ICRISAT
Archival Report
2009

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**International Crops Research Institute
for the Semi-Arid Tropics**

ICRISAT Archival Report 2009

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Contents

MTP Project 1: **Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT**

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Project profile:

This project is implemented in accordance with CGIAR System Priority 5 -- Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger. It specifically covers priorities 5A, 5B, 5C and 5D. This project provides the essential social science context for ICRISAT research. Strategic assessments for agricultural and economic growth in the semi-arid tropics are vital. This project also focuses on mapping the complex development pathways and alternative livelihood options to help make critical interventions to address poverty, vulnerability, marginalization and social exclusion.

Project 1 is coordinated through the Global Theme on Institutions, Markets, Policy and Impacts. The project implements social science and policy research at ICRISAT with focus on improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT. ICRISAT's social science and policy research thrust is to inform and provide strategic direction and prioritization of research issues within an IGNRM context and to provide appropriate capacity building. It scrutinizes the key driving factors influencing farmer to market linkages, optimal input and output options (including seed systems) and more effective policy and impact generation. Through social science and policy research, the Institute builds an enhanced capacity to help generate pro-poor policies, tools, lessons, and investment guidelines that contribute to improved food security, livelihood resilience and poverty reduction while protecting the environment of the production systems in the semi-arid tropics. As the poor faces a wide range of social and economic constraints, ICRISAT maintains a constant communication with them through village level studies to understand their needs and seek solutions. In this way, ICRISAT generates and shares vital information and analytical tools that provide a rational foundation for decisions that will benefit poor farmers and consumers.

Objectives

- Evaluate and develop alternative institutional arrangements and policy options for expanding access and utilization of new technologies and services for smallholder producers for greater impact of agricultural innovations on poverty and sustainable management of SAT agro-ecosystems (links to System Priority 5A)
- Develop and promote strategies that enhance market access and competitiveness of dryland commodities for smallholder farmers and agro-enterprises and food safety for consumers (links to System Priority 5B)
- Examine, develop and promote strategies for strengthening rural institutions and pro-poor institutional change to improve access of smallholders to markets and technologies and reducing vulnerability of livelihoods (links to System Priority 5C)
- Analyze the effectiveness of agricultural and rural development strategies and identify development pathways and policies that facilitate poverty reduction and livelihood protection under chronic and transitory emergencies (links to System Priority 5D)

In the MTP 2009-2011, Project 1 targeted ten outputs to be achieved through social science research focusing on four research areas: (1) strategic assessments, (2) rural livelihoods and development pathways, (3) market studies, outlooks, and institutional innovations, and (4) research priority and impact assessment. The research area on strategic assessments seeks to identify major changes, emerging trends, driving factors influencing agricultural transformation in the SAT, and their implications for ICRISAT's longer-term research priorities and overall research strategy. Research in rural livelihoods and development pathways addresses issues related to poverty dynamics. ICRISAT is revitalizing its Village Level Studies (VLS) to track changes in rural poverty in rural household and village economies. Research in market studies, outlooks and institutional innovations draws lessons learned from market and institutional studies and prospects for SAT mandate crops, as well as conduct research on market linkages and commercialization for technology uptake. Finally, the focus on research priority and impact assessment studies is to continue to develop analytical methods for assessment of impacts, thereby strengthening institutional capacity for analyzing impact pathways within ICRISAT and among NARS, and provide technical backstopping for adoption and impact assessment research in the other Global Themes.

GT-IMPI commenced several major projects classified under 4 research thrusts commencing 2008-09. These are mainstreamed in accordance with ICRISAT's strategic plan. Most are global projects covering South Asia, ESA and WCA and multi-disciplinary, undertaken in collaboration with the other ICRISAT Global Themes, namely GT- Crop Improvement, GT- Agroecosystems and KMS. These projects usually encompass more than one of the priority focal areas mentioned above. The major projects with GT-IMPI include

- **Village Level Studies**:
    - Asia: Tracking rural poverty in village and household economies in south Asia funded by the Bill and Melinda Gates Foundation in partnership with IRRI and NCAP
    - Sub-Saharan Africa: Assessing the Dynamics of Poverty and Land Degradation in the Sahelian countries of West Africa funded by IDRC in partnership with IFPRI, INERA and INRAN.
- **Vulnerability and Climate Change**
    - Asia: Climate Change: Vulnerability to Climate change: adaptation strategies and layers of resilience funded by the Asian Development Bank in partnership with national program partners in 7 countries of Asia namely India, Bangladesh, Pakistan, China, Sri Lanka, Thailand and Vietnam
    - Sub-Saharan Africa: Climatic risk management through Sustainable Land Management in Sub-Saharan Africa in partnership with international centers ICRISAT, ICRAF and IFPRI
- **Targeting for improved crop productivity and delivery**
    - Enhancing grain legumes' productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia funded by the Bill and Melinda Gates Foundation in partnership with IITA, CIAT and NARS in Africa and Asia
    - Harnessing the True Potential of Legumes: Economic and Knowledge Empowerment of Poor Rainfed Farmers in Asia" funded by IFAD
    - Programme for Integrated Innovations for Improving Legumes Productivity, Market Linkages and Risk Management in Eastern and Southern Africa" funded by IFAD

- o HOPE for the drylands – Cereals Project funded by the Bill and Melinda Gates Foundation in partnership with IFPRI, WFP, PASS and other NARS in Africa and Asia

- **Strategic Assessments**
  - o ICRISAT Research spillover benefits in Asia and sub-Saharan Africa
  - o IPG Potential of ICRISAT downstream research

- **Crop-livestock systems**
  - o Optimizing livelihood and environmental benefits from crop residues in smallholder crop-livestock systems in sub-Saharan Africa and South Asia: Regional case study Southern Africa (CGIAR / SLP, ICRISAT, ILRI)

Highlights for 2009

Significant IPGs
- Village-level studies database and webpage
- Innovations Platforms
- Policy harmonization tool with reference to seeds but which can be applied to all commodities following the Data→Analysis→Dialogue and →Action
- ReSAKSS-SA web page which provides a one-stop shop for information needed for agricultural policy work in the region- www.resakss.org
- Methodology for evaluating the preferences for traits by farmers in Niger, Nigeria and Mali

Outcomes and impacts achieved
- **Village Dynamics Studies - influencing eminent researchers to conduct retrospective and   prospective studies**
  The VDS study because of its innovations and linkages with respective to the scope (both horizontal and vertical), methodologies, and analytics has influenced researchers to draft a project proposal in coordination with the Planning Commission of India to study the prospects for Indian agriculture and rural poverty reduction. The outputs from the VDS project will help the researchers to conduct a major retrospective and prospective study on Indian agriculture. The longitudinal micro- and meso- level databases will help examine differences across regions, and between tribal and non-tribal districts, in public and private investment, the spread of technology, and total factor productivity growth in agriculture; the ten villages studied by ICRISAT over the last 30 years in poor semi-arid India will provide qualitative and quantitative evidence on how poor villages have responded to opportunities and constraints, and have been able to reduce poverty despite their agro-climatic disadvantages and growing populations; and the extensive ICRISAT agricultural data on all districts in India would allow for the estimation of the impact of climate change that has already happened on agricultural production, net of all farmer and policy adjustments.

- **Innovation Platforms:**
  The concept of the Innovation Platform (IPs) is defined as a development tool that facilitates dialogue between main local players in a value chain to generate site-specific solutions and develop technologies in response to market requirements. It is based on flexible partnerships and draws on relevant expertise depending on the challenges identified. The implementation is through iterative processes of improvement and evaluation.

  The IPs created structures for linkages between the key stakeholders in the livestock sectors in Mozambique, Namibia and Zimbabwe. These structures improved communication and built a base for partnerships between public and private actors. Value Chain Analysis (VCA) was used as a strategic instrument to identify key actors and their challenges, and inform the IPs.
  The IPs increased the local, national and regional capacity to understand challenges in livestock production. They identified opportunities and constraints that are most pertinent to enhance the productivity and competitiveness in the livestock sector. The dialogue in the IPs confirmed that access to information is a major limiting factor in the entire value chain in all three countries studied. Most importantly, farmers are unable to link the value of increased quality of production with increased incomes as in most areas prices are set irrespective of grades and standards.

  This IP/VCA tool has bee Studying the IP process contributed to the definition of the innovation-led development tool. Lessons were learned from the various site experiences and at various levels in the value chain - improved access to inputs and services, alternative market channels, processing infrastructure, institutional weaknesses. These lessons were incorporated into the development tool that helps to set up IPs, organize and manage the process. It uses VCA to indicate pressure points and identify entry points for technology, market and institutional development that increase efficiencies of value chains as whole entities.

  n used to conceptualize a project proposal/idea note on Public-private Partnerships for enhanced market and technology development in crop livestock systems of southern Africa. The IP tool can be applied to other contexts and commodities. Several SADC projects requested support in implementing the IP/VCA tool, e.g. the DONATA project in Mozambique on cereals (sorghum, millet and maize) and the SCARDA, Botswana Commodity Value Chain project on livestock. ILRI has requested to use the IP/VCA tool for its projects in West Africa.

Achievements in 2009

Output 1: Best innovative practices and mechanisms for harmonization and utilization of seed-related and biosafety regulations and policies suitable for the specific conditions of the SAT piloted, promoted and adopted with new knowledge shared with partners. [This output is shared regionally with projects 3 and 4]

System Priority 5: Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger

Priority 5A: Improving Science and Technology Policies and Institutions

Priority 5A, Specific goal 3: Improving incentives for technology generation, access and use

This research area is closely linked to that of Projects 3-6 but as a global generic policy issue it is felt it would be better to address it as a whole in Project 1 rather than to disarticulate it between 4 other projects.

Project: Seed Policy Harmonization (SCOSA)

Output target in 2010 1.1.1 Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the ASARECA (2010) region promoted

Intermediate target output in 2009: SADC Seed Systems Development Initiative

Achievement of Output Target (%):
 85%
Seed security is a precursor to food security because its availability and quality determine the potential to crop production and productivity. In the SADC region, however, good quality seed of improved varieties is not available, especially to small scale farmers who are responsible for ensuring household, national and regional food security.

Participating Countries:
Angola, Democratic Republic of Congo, Malawi, Mauritius, Madagascar, Mozambique, Lesotho, Swaziland, South Africa, Tanzania, Namibia, Zambia, Zimbabwe

Participating Partners:
Iowa State University, private sector seed Companies, National Seed Trade Associations in the SADC countries and the NARES of SADC

Progress/Results:
The seed systems development initiative was coordinated in the 14 countries of SADC with a view to harmonize essentially four main seed issues in the region—variety evaluation, release and registration procedures, seed certification, phytosanitary regulations and import and export procedures for seed. Important to note is that ICRISAT subcontracts Iowa State University—the Seed Center to work in this project.

The main achievements were as follows:
Strategic discussions with donors: There were deliberations and exchange of information amongst ICRISAT, Swiss Agency for International Cooperation (SDC), USAID-RCSA and the project implementation team. These discussions centered mainly on positioning of the seed systems improvement efforts in the SADC region by SDC and USAID for increased efficiency in the use of available resources and impact. The discussions aimed at modalities for ensuring continuity of work initially performed by the SADC Seed security Unit (SSSN).

Participation in partners' meetings: USAID/Southern Africa organized two planning meetings—at Stellenbosch University and FANRPAN-Pretoria for partners (those that are funded by USAID). The main agenda for these meetings were to exchange and share progress on work plans. The meeting discussed among other things monitoring and evaluation of activities, data collection and reporting, current work plans, funding and the flow of funds and how to carry out future activities efficiently. Attending the meetings were representatives from the International Potato Center-Sub Saharan Africa (CIP-SSA), CIP-Nairobi, Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN), ASNAPP and ICRISAT.

Distribution of project materials to stakeholders: During the period under review, 800 Seed technical agreement monographs printed by ICRISAT were distributed to individuals, SADC member states, and the SADC secretariat. They were published in three different languages − English, French and Portuguese. There is an intention to continue the distribution of the monographs in the coming year so that more stakeholders can read, understand and be aware of the agreements.

The crop protection compendium is a time saving encyclopedic, interactive database that draws together scientific information on all aspects of crop protection. Fifty two compact discs (CD RoMs) of the crop protection compendium were bought from CABI in August 2009. It includes information on pests, diseases and weeds and their natural enemies, the crops that are their hosts and the countries in which they occur. It assists in updating the number of quarantine pest list and diseases of economic importance based on science in the region.

Updating and development of seed regulatory framework in accordance with the regional agreements: The updating and development of seed regulatory framework was coordinated in the 14 countries of SADC in accordance with the seed technical agreements. This was done in part by organizing three regional workshops—namely; seed import /export workshop held in Lusaka, Zambia, training workshop on establishing plant breeders rights in countries were they do not exist (held in Pretoria). In the same workshop, seed law and plant variety protection legal frameworks were developed. A third workshop was training on the management and administration of web-based variety catalogue held in Lusaka, Zambia.

Technical backstopping support to the seed certification and accreditation: The process of Iowa State University in engaging with seed companies and the NARES with a view to couch them on the needed reforms following the technical agreements was well coordinated.

Establishment of a regional tool for monitoring costs, volume and value of seed trade harmonization: This activity was initiated following the realization that the seed policies harmonization will have a significant bearing on reducing transaction costs and time constraints faced by seed trade in the region. There is a perceived reduction in transaction costs and increase in volumes of seed traded due to seed policies harmonization. The seed trade agreements are not yet operational; therefore, it is essential that tools for monitoring success emanating from the seed trade agreements are sharpened and understood and used by SADC countries. Work pertaining to this tool is still ongoing. An external reviewer assessed the paper and we intend to publish this paper after incorporation of comments from the reviewer.

Championing the coordination of partners of the budding Eastern and Southern Africa Seed Alliance (ESASA): An attempt was made through different ways to bring the key partners together—and in particular during the attendance of the Agri-business forum in Cape Town in June 2009. The current decision that evolved regarding the change in the branding to Seed Industries Alliance for Eastern and Southern Africa. The agenda though, remains the same.

Support to the SADC plant protection technical committee 7th ordinary meeting: The SADC plant protection technical committee was held that deals with issues related to phytosanitary measures, integrated plant protection and cross-cutting issues such as policy harmonization,

capacity building and networking. The work of the SADC Plant Protection Technical Committee is of great relevance to the harmonization of seed policies in the region, especially the component that deals with phytosanitary measures for seed. The meeting was successfully held and attended by 11 Member States namely Angola, Botswana, Lesotho, Malawi, Mauritius, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. The IRLCO-CSA (International Red Locust Control Organization for Central and Southern Africa) and ICOSAMP (Information Core for Southern African Migrant Pests) were instrumental in providing knowledge to participants on the subject. The meeting provided an excellent opportunity for the countries of the region to share and exchange experiences on matters regarding plant pests and diseases in the SADC countries, first on a regional basis and second on a country-by-country basis.

Proposal development targeting Swiss Agency for International Development and USAID-SA—in collaboration with Iowa State University, a proposal dubbed MBEGU was developed and submitted jointly to Swiss and USAID with a view for leveraging more funds for the implementation of the seed work in the region. This proposal reached an advanced stage but it was clear that due to some technicalities on the part of the donors, the funding will have to be made separate—Swiss and USAID.

Special Project Funding:
USAID project funding facilitated this activity at a funding level of US $ 350,000

<div align="right">Isaac Minde and team</div>

Output 2: Ex-ante and ex-post impact studies conducted on representative ICRISAT NARS innovations for the SAT to enhance accountability and facilitate priority setting

Priority 5A, Specific goal 5: Enhancing the structure, conduct and performance of knowledge-intensive institutions

Output target 2010 1.2.1 Tropical Legumes/IFAD project early adoption studies on chick pea, pigeon pea and groundnut in selected countries

Intermediate target output in 2009: *Baseline studies across all target regions for the targeted legumes crops are completed. The key findings for the baseline studies will feed into the early adoption studies that are planned in 2010.*

Achievement of Output Target:
50%
The project's targeting and impact strategy employs the commodity chain approach and is strongly oriented towards the full range of clients. It is supported by farm-level baseline surveys and the feedback provided by participatory diagnosis of constraints. The elements of this approach include the following: (i) analysis of constraints to identify potential intervention strategies in the context of holistic value chain approaches – with research supported by situation and outlook analysis, baseline surveys and active participation of stakeholders along the value chain; and (ii) analysis of constraints and uptake pathways to draw out valuable lessons and develop mechanisms that can be used to increase adoption and impacts.

Participating Countries:
India, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Mali, Niger, and Nigeria

Participating Partners:
Asia: ICRISAT, University of Agriculture Sciences, Bangalore; University of Agriculture Sciences; Dharwad; Punjabrao Krishi Vishwavidyalaya (PKVK), Akola; Tamil Nadu Agricultural University, (TNAU) Coimbatore; Acharya NG Ranga Agricultural University, Hyderabad

SSA : IITA, CIAT, TSBF-CIAT and NARS from Ethiopia, India, Malawi, Mozambique, Nigeria, Niger, Mali, Kenya and Tanzania that are involved in legume improvement research especially groundnut, chickpea, pigeonpea, soybean, cowpea and beans.

Progress/Results:
The key findings for the baseline studies across all regions for the targeted legume crops are analyzed and synthesized with focus on the following aspects:
- Ruling varieties;
- Baseline adoption;
- Baseline yield/current yield gap;
- Preferences across the value chain;
- Gender issues;
- Marketed surplus.

Ruling varieties: The baseline survey results and the qualitative assessments through discussions with key informants and Focus Group Meetings clearly indicate the continued dominance of certain varieties that were introduced in the target locations several decades ago. A listing of all the 'ruling varieties' as they are called henceforth, by crop and region is presented below. This observation calls for an investigation of the reasons for the low uptake of the improved, high-yielding varieties resulting from the collaborative research by IARCs and NARS.

Baseline adoption: The baseline reports summarize the historical development and adoption of both local and improved varieties of the targeted legume crops in SSA and SA. The highlights are given in the full report.

Baseline yield/ current yield gap: In the traditional farming systems in which much of the tropical legumes are grown by small scale farmers with little or no input, the yields are in general low.. Significant yield variation across farmers were observed both for local and improved varieties in irrigated and rainfed conditions.

Preferences across the value chain: The preferred traits by the different actors and players along the value chain were documented as part of the baseline surveys. While farmers are interested in high yields and economic gains, the processors and traders were also keen on the quality standards like uniformity in size, grain size, cleanliness and healthy grains. Consumers, on the other hand, had preferences for taste, cooking quality and time and keeping quality.

The question then that needs to be addressed is how we match the mandate and preferences of the researchers with those of the farmers right upto the consumers. What are the implications of these findings to the researchers, and to policy makers? This has to be understood in order to establish a feedback mechanism in place.

Gender issues:
An analysis of the baseline data relevant to gender issues provides important feedback for breeders and policy makers. Two examples featured in the report are:
  • In West Africa, cowpea provides a source of cash income for women farmers who make and sell snacks from cowpea. Most of the green pod marketing from this nutritious legume is handled by women. In many African countries, women harvest and sell directly to consumer on roadsides, because pod prices are higher than dry grain prices. The role of gender appears to be important in grain retail trade in Africa;
  • In Ethiopia, common bean production and marketing is dominated by men. Males dominate the implementation of almost all management practices except hand weeding and harvesting the crop where both genders participate. Men contribute about three times as much labour as women in the production of common bean. They are also responsible for the bulk sale of white pea beans as assemblers and rural wholesalers. Men constituted about 87 percent of bean traders in Ethiopia. On the other hand, women sell small quantities as retailers in markets.

Marketed surplus:
The marketed surpluses of the three targeted crops vary. In India, 70-80% of the harvest is sold immediately after harvest. A majority of the harvested produce is sold to the village traders owing to prior input- credit contracts. The market price that the farmers get in this situation is typically lower than when they sell their produce directly to the processor. Information on prices is not widely available and the sample farmers rely on unofficial sources such as neighboring farmers or village traders. Further, the different actors in the value chain are spread out geographically and information about prices is not available in one place- for example in chickpea markets in Ongole and groundnut markets in Anantapur. There are many links in the chain between the sample farmers and processors/ consumers that further erode the farmer's share in the consumers' rupee. This extended marketing chain exists owing to the fact that there is no common marketing platform where all the value chain actors can carry out their transactions. Processors prefer to buy whole grain in bulk in order to cut down on their transaction costs. However, since a majority of the sample farmers are small scale farmers with small marketable surpluses, a commission agent who collects all the grain from the farmers, and sells it to the processors in bulk quantity becomes an important actor in the value chain. Regional annual progress reports by target legume crops submitted by the respective regional project coordinators

Special Project Funding:
Bill and Melinda Gates Foundation

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MCS Bantilan, P Parthasarathy Rao, KPC Rao, VR Kiresur, B Shiferaw,
J Ndjeunga, S Asfaw, Ousmane Coulibaly, AD Alene, Jonas Chianu,
Enid Katungi, Andy Farrow, H Tefera, S Boahen, T Abdoulaye,
V Manyong, D Chikoye, D Sanogo and NARS partners in India, Mali,
Niger, Nigeria, Ethiopia, Kenya, Malawi, Mozambique and Tanzania
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Intermediate output target in 2009: *Baseline report (Niger, Nigeria and Mali)*

Achievement of Output Target:
50%
The baseline surveys will support the analysis of constraints and work to identify intervention strategies in the context of holistic value chain approaches along with the participatory work with the stake holders and ex-ante impact studies.

Participating Countries:
Niger, Nigeria and Mali

Objective:
Baseline studies across all target regions for the targeted legumes crops

Methodology:
The analysis of baseline data completed and baseline reports on households and markets are completed. This activity is divided into 2 parts: a household data and market data.

The household data involves a thorough analysis of 15 modules including (1) the socio-demographic profile of households, (2) land stock and utilization, (3) knowledge of groundnut varieties and source of first information, (4) varieties currently grown and disadoption, (5) input and output data, (6) stock, production and consumption of agricultural products, (7) sales and purchases of agricultural products, (8) sales and purchases of livestock, (9) household commercial behavior (contractual arrangements, contract enforcement and transaction costs), (10) Household assets, (11) household access to credit, (12) household social capital – affiliation to institutions, (13) Desirable groundnut qualities and (14) household food security and income shocks.

This report presents the achievements from the sending last 2 years of the Tropical Legumes II project focusing on groundnut seed systems and targeting interventions in West Africa.

Participating Partners:
NARS partners in the target countries

Progress/Results
Mali: Baseline database available. Data collected on 166 households and 40 traders in the Kolokani and Kayes regions of Mali in 4 project sites. Data fully analyzed and report being prepared by IER economist. Preliminary results available

Niger: Baseline database available. Data collected on 348 households and 160 traders in the region of Dosso in Niger. Data fully analyzed and report being written by INRAN economist. Preliminary results available provide the following information.

Nigeria: Baseline database available. Data collected on 277 households and 70 traders in the survey sites. Data fully analyzed and report being prepared by IAR economist. Preliminary results available. In Niger, household survey results show that the variety 55-437 introduced more than 40 years ago is being used by more than 74% of surveyed households. However, it was found that an estimated 12% of households are using one of the newly introduced varieties RRB (other new varieties recently introduced include J11, Fleur 11 and ICG 9346). There are significant differences between project and non-project sites as about 16% of households were using RRB in project sites against 4% in non-project sites. There are still significant yield gaps. The average yield estimated from the survey is 537 kg/ha against a gap of about 463 kg/ha obtained on farmers' fields under normal input use. The major constraints to planting varieties during the 2007/08 season were listed as unavailability of seed (42%), loss due to drought (24%) and low oil content (18%). Few farmers cited the lack of funds to purchase seed (4%), lack of information on crop management of alternative varieties (4%), or low yield (8%). Households sell about 759 kg of groundnut pod account to about 76% of the total production.

In Nigeria, household survey results showed that the variety 55-437 introduced more than 40 years ago was still being used by about 72% of surveyed households. About 23% of the farmers reported using at least one newly introduced variety (SAMNUT21, SAMNUT 22 and SAMNUT 23). The yield gaps were still very important. Yields were estimated to 850 kg/ha whereas the optimal yield obtained under farmers' conductions were estimated at 1500 kg/ha. Seed was reported to be poorly accessible for farmers who were exposed to the technology but could not test these varieties. In addition, for farmers who adopted these technologies, access and availability of seed was reported to the major constraints. Households sell about 954 kg of groundnut pod account to about 64% of the total production. The major constraints to planting alternative varieties during the 2007/08 season were listed as unavailability of seed (39%), late maturity (13%), the low market value (13%), low yield (8%) and loss due to drought (2.80%).

In Mali, the baseline household surveys were undertaken in 4 sites of the Kolokani and Kayes in Mali. A total of 166 households were interviewed of which 111 farmers in the project sites and 55 households in the control sites. Results from the survey indicate that the ruling variety 47-10 is being grown by about 41% of surveyed farmers and that 43% of the surveyed farmers are using at least one newly introduced variety (JL 24, Fleur 11, ICGV 86124, ICGV 86015, ICG(FDRS)4). Yield levels were found very low estimated to about 676 kg/ha, with a yield gap of about 424 kg/ha. The major constraints to uptake of varieties remain the availability to seed of alternative varieties. In effect, it is estimated that about 34% of farmers claimed that the major constraints is seed availability, followed by drought, low yield, etc... Households sell about 376 kg of groundnut pod account to about 74% of the total production.

Gender issues:
In Niger, where women are involved in groundnut production, they are given the poorest land, can only plant smaller area than men (0.96 ha for women against 2.30 ha for men), but are more efficient at managing their plots. In effect, the average yield in women plots is estimated to about 734 kg/ha against 410 kg/ha for men. There were no difference found in the access to inputs such as fertilizers, pesticides and insecticides but access to agricultural equipment was limited because men have to finish plowing their land before women have access to equipment.

Farmers, and market preferred traits reflecting gender dimensions
We evaluate farmers' preference for different groundnut varieties' characteristics using a random utility-based choice experiment and ordered probit analyses. Data were collected through a structured panelist survey administered at 6 project sites in the Dosso region in Western Niger, 6 project sites in Northern Nigeria and 4 project sites in Mali .

In Niger, the preference survey was conducted in the villages- project sites Doula, Guidan Gaba, Koma Beri, Tanda and Wassangou. Six varieties were used mainly RRB, J11, Fleur 11, ICG9346, TS32-1 and 55-437 as a check. A total 114 panelists participated at harvest of which 25% were women. In Nigeria, 155 panelists all men participated in the Jigawa, Kano and Katsina states and six varieties were used in the test mainly SAMNUT21, SAMNUT22, SAMNUT 23, ICIAR19AT, ICIAR6AT and ICIAR7B. In Mali, A total of 74 panelists were involved in the regions of Koulikoro and Kolokani of which 60% of women. Six varieties were also used in the test including ICG 86124, ICG(FDRS)4, Fleur 11, JL 24, etc…

Preferences were estimated for various plant and seed traits from various varieties. In Niger, results showed that the resistance to diseases, green color of leaves, and high number of pods, bec, reddish grain color, and pod yields were the major characteristics preferred by farmers. In Mali, early maturity, high number of pods, the large sized pods, pod filling, pod yields, reticulation and strangulation were the main traits sought by farmers. In Nigeria, high plant vigor, early maturity, type of port, number of pods, high sized pods, high pod yield and high haulm yield were found to be the most significant characteristics sought by panelists.

There were however no differences based on gender in Mali and Niger or other socio-economic characteristics such as age, ethnic group, level of education and wealth. These characteristics should be accounted for when designing or selecting groundnut varieties likely to be preferred by groundnut farmers. The results have bearing in research priority settings.

The partners NARS economists have shown little interest in contributing to write-up of baseline reports. This activity ended up being an ICRISAT activity entirely.

The market data is more limited and the quality of data may be questionable as many intermediaries are not keen to share their transactions and commercial behavior. Efforts will be made to extract information from the data. Data collected on retailers, rural assemblers, wholesalers based on purchases, sales and transaction costs will be analyzed.

MCS Bantilan, P Parthasarathy Rao, KPC Rao, VR Kiresur, B Shiferaw, J Ndjeunga, S Asfaw, Ousmane Coulibaly, AD Alene, Jonas Chianu, Enid Katungi, Andy Farrow, H Tefera, S Boahen, T Abdoulaye, V Manyong, D Chikoye, D Sanogo and NARS partners in India, Mali, Niger, Nigeria, Ethiopia, Kenya, Malawi, Mozambique and Tanzania

Intermediate target output in 2009: *Treasure Legumes*

Achievement of Output Target:
50%
The baseline studies for the targeted legumes provide information on varied aspects at household and village/community in the targeted areas.

Participating Countries:
Ethiopia, Kenya, Malawi and Tanzania

Participating Partners:
NARS from Ethiopia, Malawi, Kenya and Tanzania that are involved in legume improvement research especially groundnut, chickpea and pigeonpea.

Objectives:
Baseline studies across all target regions for the targeted legumes crops

Methodology:
This is one of the most demanding activities and milestones undertaken during the first two years. This started with extensive discussions with various partners, including the project breeders and seed systems specialists, and visits to the project sites to identify the key issues to be captured in the baseline data. A standardized survey instrument was then developed at two levels (household and village/community) for all countries to gather comparable data for understanding limiting constraints, farmer and market preferences and measuring adoption and multi-dimensional impacts of the project. Baseline data has been collected for all the three crops in three target countries (pigeonpea and groundnut in Malawi and Tanzania, and chickpea in Ethiopia) and personnel from local partners were trained in methods for survey design, sampling and good practices in administering survey instruments. About 39 local staff and supervisors were trained and the instruments were pre-tested before the surveys were administered using personal interviews. The baseline studies also benefited from other complimentary projects (e.g. Treasure Legumes project supported by IFAD) in terms of sharing fixed costs which allowed surveying a larger sample of the target farmers.

In Ethiopia a combination of stratified and purposive sampling methods was used to select the three districts included in the survey in the project target areas, namely Gimbichu, Lume-Ejere and Minjar-Shenkora. These districts represent one of the major chickpea growing areas in the country where new varieties are beginning to be adopted by farmers. Eight *kebeles* from each of Gimbichu and Lume-Ejere districts and ten *kebeles* from Minjar-Shenkora district were randomly selected from where a random sample of 700 households was selected for detailed household survey. This include 400 households in the two districts (Minjar-Shenkora and Gimbichu) targeted under the TL-II project and 300 households in the one district (Lume-Ejere) selected for IFAD project. Village level data was also collected from about 40 villages that fall within the 26 *kebeles*. EIAR/DZARC took the lead for the baseline survey in Ethiopia. While the larger datasets help understand the broader production and market constraints for chickpea in Ethiopia, the data from the 400 households will be relevant in evaluating the adoption and impact of the TL-II project.

In Malawi a total of 594 randomly selected households were surveyed in four purposively selected districts. The multi-stage sampling process included selection of 16 Sections (four per district) and 48 villages (four randomly selected among the groundnut and pigeonpea growing villages in each Section). The sample included 298 households in two districts (Michinji and Balala) targeted under the TL-II project and 296 households in two other districts (Thyolo and Chiradzulu) under the sister project supported by IFAD. The village level data was also collected from 47 villages in the four districts. About 22% of the sampled households were female-headed, while about 50% of the respondents were also females. The Malawi baseline was coordinated by ICRISAT-Malawi with support from the University of Malawi.

In Tanzania the sampling framework is based on a random sample of villages in four districts in the Northern zone, representing the main pigeonpea and groundnut growing division and wards in Babati and Kondoa and pigeonpea growing areas in the two districts of Arumeru and Karatu. In each of the four districts three major divisions were selected giving rise to a total of 12 divisions. Subsequently, two wards were sampled in each of the selected divisions resulting into a total of 24 wards. Twenty five farmers were then randomly sampled from a list of farm families in each village and ward. A total of 600 farm households (of which 50% were supported under the IFAD project) in four districts were surveyed using the standardized survey instrument. In addition to household surveys, a total of 24 communities/villages (6 from each of the survey districts) were also surveyed using key informants to gather data on broader village/community level socioeconomic factors. The survey was undertaken in collaboration with the Selian Agricultural Research Institute (SARI) and was administered from October to December 2008.

The data was subsequently transferred into STATA econometric software package for the analysis. The data was further checked for consistency and completeness and analyzed. Descriptive statistics such as frequencies, cross-tabulations, means and ratio were employed to analyze, summarize and present the data in the baseline report. Analysis was conducted by disaggregating important relevant information by districts and crops so that a snapshot comparison can be made as needed. In order to improve data quality and comparability across countries, data entry, analysis and write up of the report is led by ICRISAT Nairobi. Lack of skilled socioeconomics support within the collaborating national programs also made it difficult to enter, code and manage the data and lead the analysis at the local level. At the time of reporting analysis and write up of baseline reports for Ethiopia and Malawi have been completed while the analysis and report writing for the Tanzania dataset is underway.

Progress/Results:
The key findings for the baseline studies across all countries for the targeted legume crops are analyzed and synthesized with focus on the following aspects: ruling varieties and baseline adoption; baseline yield/current yield gap; preferences across the value chain; gender issues; market participation and marketed surplus

Adoption of improved varieties and the ruling variety: The baseline survey results clearly indicate the continued dominance of certain varieties that were introduced in the target locations several decades ago. Taking the case of chickpea in Ethiopia as an example, baseline survey results reveal that local desi are the common chickpea varieties grown in the study areas. In Ethiopia, the proportion of chickpea farmers who planted improved desi during 2007 is less than 3% while about 76% planted the local desi. About 54.5% of the chickpea area is

allocated to local desi followed by shasho (21%) and ejere (11.9%). The baseline adoption of groundnut varieties in ESA namely Chalimbana is found to be the highest. Results indicate that though Chalimbana is the most widely known variety (84%) followed by CG7 (53%) and manipintar (11%), only 69% have ever grown the variety and only 43% grew this in 2007/08. In ESA, 71% of the farmers know the local pigeonpea but only 57% have ever grown it and only 31% grew the crop in 2007/08 season. For Mthawajuni variety, 53% knew the crop, while 44% actually grew it in 2007/08. Overall the sample adoption rate of improved pigeonpea variety in Malawi is about 10%. However, if the technology would have been universally known within the population, the potential adoption rate would be higher (about 45%).

Baseline yield/ current yield gap: In the traditional farming systems in which much of the tropical legumes are grown by small scale farmers with little or no input, the yields are in general low. For instance in Ethiopia the chickpea yield is estimated to be 2236 kg/ha for local cultivars and 2710 kg/ha for Arerti. High pest incidence, small grain size, low market price, low recovery/shelling percentage, high disease incidence and long crop duration are main constraints to improving chickpea productivity in SA as well as ESA.

Preferences across the value chain: The preferred traits by the different actors and players along the value chain were documented as part of the baseline surveys. While farmers are interested in high grain yield, larger grain size, resistance to insect pests and diseases, drought-tolerance and higher fodder yield, the processors and traders were also keen on the quality standards like uniformity in size, grain size, cleanliness and healthy grains. The consumers on the other hand had preferences for taste, cooking quality and time and keeping quality

Gender issues: In ESA, 22% of sample households were headed by women and 50% of the respondents were also women. Women participate in almost all activities with respect to crop production; women are more heavily involved in the production chain than men. Marketing activities are carried out by men. While men take decisions on economic matters, decisions regarding crop production, and education and marriages of children are taken jointly. Participation of women farmers in mother/baby trails is limited, particularly in Asia. There was generally poor access and ownership to resources by women.

Market participation and marketed surplus: In Ethiopia, about 37% and 64% of chickpea farmers have participated in the marketing of kabuli and desi chickpea, respectively. The marketed surplus for kabuli chickpea is about 293.7 kg which is higher than desi types (217 kg) and overall chickpea is the fourth in terms of quantity sold in markets. About 89% of chickpea producers used donkeys for transporting while about 15% used public means to ship chickpea to the market. Urban grain traders are the first major buyers of chickpea in all the three districts followed by rural traders and rural assemblers. In Malawi, about 73% of the groundnut farmers participated in groundnuts marketing. Each of the farmers sold an average amount of 137 kg of groundnuts. The degree of market participations appear to vary with the type of variety grown. In general more than three-quarters of the farmers that planted chalimbana2005 (improved variety), sold some of the produce while marketing of produce for farmers that grew other varieties is slightly lower. Results for pigeonpea indicate that 91% of the pigeonpea farmers sold some pigeonpea, and that only 29% of the pigeonpea produced is marketed. On average, farmers sold about 71 kg of pigeonpea per year. The major mode of transport to market pigeonpea and groundnuts is carrying on head or head-load and walking on foot (38%). However, the use of head load is particularly more prevalent among pigeonpea farmers (50%) than among the groundnut producers (27%). About a quarter of farmers that marketed their crop used the bicycle to transport their produce

Bekele Shiferaw

Intermediate output target in 2009: *Groundnut seed supply systems (WCA)*

Achievement of Output target:
100%

Participating Countries:
Niger, Nigeria and Mali

Participating Partners:
NARS, Private sector, Farmers Associations from the participating countries

Progress/Results:
Pilot testing small pack groundnut seed in Niger
The demand for small pack seed available piloted with the following highlights. The demand for seed of coarse grains (sorghum and pearl millet) or leguminous such as groundnut is argued to be very limited. The market for such improved seed is thin because most farmers save seed from past harvests and thus do not participate in seed markets. This paper presents the results from a pilot experiment to assess the potential demand for seed by smallholder farmers in the Dosso region in Niger. Two major hypotheses were pursued mainly the optimal pack size and the effect of seed treatment on the demand. Results showed that more than 64% of groundnut seed stocks were sold, of which 78% of 5 kg pack, followed by 73% of 1 kg size, 61% of 2 kg packs and lastly 55% of 0.5 kg size. Sixty-nine per cent of the treated seed were purchased but not significantly different from the untreated seed estimated to 57%. There are however significant differences between selling points based on the positioning of selling points, the level of knowledge of agro-dealers and small-scale retailers on marketing and business skills and the agro-ecological zone. All selling points located in the local markets sold on average 79% of the seed stocks significantly more than selling points located far from the local markets estimated to 40%.

The levels of sale in selling points located in drier areas was lower in drier areas (48%) compared to less drier area estimated at more than 78%. The level of knowledge was not found significant though shops managers with better knowledge in marketing and business skills sold 70% of their seed stocks against 55% for those with poor knowledge. This operation was not found profitable due to a range of factors including the location of selling points and the limited marketing and business skills of shop tenants. From a small-scale private entrepreneur point of view, this operation yielded losses estimated at US$0.51/kg of seed. Profitability of such small-scale seed enterprises will increase significantly if selling points are better located ie. in local markets, agro-dealers are well trained in small-scale marketing and business skills and the size of the seed pack should be above 1 kg. This experiment will be repeated once more during the second year in a much larger scale.

Following the identification of these constraints, in March-April 2009, a training program of agro-dealers was undertaken with CNFA-WASA expertise. Another experiment was undertaken with trained agro-dealers. Though there were improvements in market efficient, about 20 farmers trained in marketing and agribusiness skills established their own small-scale seed enterprise businesses.

Cost-benefit analyses of different foundation/certified seed supply schemes assessed
Data on cost of seed production has been collected with all partners involved. Essentially, it is estimated that the average cost of basic seed produced varies between US$0.87 with Alheri Seed Company in Niger to about US$3.28 at IER Mali. As for the production of certified seed, it varied between $US0.86 by Alheri Seed Company to about US$1.86 by farmers' associations in Nigeria. This high variability in unit cost of production is largely explained by high labor costs involved in land preparation, weeding and harvesting.

When examining the structure of the costs, it is estimated that 19% of cost in invested on average it is estimated on weeding, 20% on fertilizer cost and 22% on harvest. Other costs such as field inspection for quality control are estimated on average at 7% of the total costs, seed costs at 7.5% and land preparation at 5.43%.

These partial results showed that basic and certified seed can be produced at lower costs by farmers, farmers' associations and the private sector. There is a need to strengthen, empowered and tasked local institutions with the production of these seed classes. Seed laws and regulations in countries should target local institutions such as small-scale seed producers, farmers' associations and the private sector with production of seed of basic, certified, and quality declared seed. Governments should encourage and facilitate access to credit to finance labor and fertilizer costs.

Constraints to seed supply and opportunities updated
In all the 3 countries, seed supply channels have been identified and characterized. In all the countries, variety development is undertaken by NARS with technical backstopping of ICRISAT. Variety release is undertaken by the National species and Variety release committee (CREV) in Mali, and by the Crop Variety Registration and Release Committee (CVRRC) in Nigeria. There is no variety release committee in Niger. In all the 3 countries, breeder seed is produced by both NARS and ICRISAT, while foundation seed is produced by NARS, small-scale seed producers, farmers' associations in Mali and Niger. However, foundation seed is produced by IAR, ADPs and the private sector in Nigeria. Farmers' associations and small-scale seed producers are not directly associated with seed production and delivery. Commercial seed production involved the private sector, small-scale seed producers and farmers' associations in Mali and Niger.

Seed is supplied through 2 main channels: the informal and the formal channels. The informal channel comprises village markets and farmer-to-farmer exchange whereas the formal channel includes extension services, rural development projects, NGOs, farmers' organizations and the small emerging private company in Mali. Similar schemes are observed in Niger and Nigeria.

In Niger, survey results showed that more than 60% of the surveyed farmers saved their seed from past harvest, more than 12% purchased seed in the village markets and 7% obtained seed from friends and family. Similar trends are observed in Mali and Nigeria. Between farmers demanding seed, about 55% obtained seed free while 19% buy seed with cash and 9% on credit. Barter transactions are also important and account for about 16% of the seed transactions in Niger. Similar trends are recorded in other countries.
The major constraints facing the seed industry include the poor seed demand estimation and non-flexible seed laws and regulations. Seed sources and transactions show the need to strengthen local village seed systems at supplying seed to many farmers. These local institutions need to be tasked with the production and delivery of seed.

Training farmers in marketing and small-scale business skills
In Mali, 25 seed producers and processors were trained in marketing and small business skills. And in Niger, 32 seed producers, leaders of farmers' associations and processors have been trained in the Gaya region in Niger.

Lessons learned
- Small-scale seed producers and farmers' associations can produce and deliver basic and certified groundnut seed.
- There are market niches for sales of small pack seed and small pack sales are major vehicle for variety diffusion.
- Training in seed marketing and small-scale business skills is essential in stimulating small-scale private sector interest to engage in the seed industry.
- The private sector is slow to emerge and needs to be incubated.
- Partnership with WASA/AGRA needs to be strengthened to avoid duplications.
- Academic training is a prerequisite to building capacity in West Africa and better interact with partners.
- Need to engage in seed laws and regulations to make it flexible and engage many more actors in the groundnut seed chain.

Special Project Funding:
Data not available

Jupiter Ndjeunga

Output target 2009 1.2.1 Ex-post impact studies on sorghum and pearl millet in Nigeria; sorghum and pearl millet for poultry feed in Asia

Achievement of Output Target:
50% (West and Central Africa)
To undertake an exhaustive documentation and synthesis of the research benefits from sorghum and pearl millet research in WCA and analyze the results of the adoption and impacts studies on sorghum and millet improved varieties in WCA

Participating Countries:
Nigeria and Mali

Participating Partners:
NARS partners from Nigeria and Mali

Objectives:
Assess the impact of sorghum and pearl millet varieties on Northern Nigeria and Mali

Methodology:
The study was carried out in Northern Nigeria involving 6 states major producers of sorghum and pearl millet mainly Katsina, Kano, Jigawa, Borno, Yobe and Zamfara. A total of 1200 households major pearl millet and sorghum producers were selected proportionally to rural population size in each state.

Progress/Results:
This is a critical activity that will be presented during the next ICRISAT board meeting. This activity is already on-going in Nigeria. After interaction with key resource persons (sorghum and pearl millet breeders in Nigeria) on the research process and technology diffusion, six states (Kano, Katsina, Jigawa, Yobe, Zamfara and Borno), major sorghum and pearl millet producers were selected in Nigeria. Using stratified random sampling based on rural population and a total number of villages set to 120, the number of villages to be selected per state was computed. Thus, 29 villages were selected Kano state, 23 in Katsina, 20 in Jigawa, 12 in Yobe, 16 in Zamfara and 19 in Borno state. In each village, 10 households were selected making a total of 1200 households sufficiently representative to draw firm conclusions on uptake, adoption and impacts.

Questionnaires were developed at village and household levels. Village information includes GPS coordinates and village road access, access to markets and other services; land occupation, relative importance of crop and land tenure, programs and organizations promoting improved seed of modern sorghum and pearl millet varieties or agricultural/livestock management practices (participatory variety selection, demonstrations, pearl millet or sorghum seed projects, other seed projects, research station, research farm, farmer field school, etc…); Prices of outputs, inputs and factors of production, livestock prices in 1999 and 2009, Agricultural input use and prices in 2009, wages, credit sources and costs, units of measurements, major that have occurred in the village and how did you solve these? And enumerators' comments.

Household information includes household socio-economic and demographic characteristics, Diffusion mechanisms of sorghum and pearl millet varieties, Use of technologies in pearl millet and sorghum fields by households in 2008/09, Crop stocks, production, and consumption in 2008/09 and 1999/00, Marketing of crops during the 2008/09 season – Sales (including crop residues, fodder products …etc), Livestock – Live animals. Stocks, Production, and Consumption during the 2008/09 and 1999/00 cropping season, Household Assets owned in 2008/09 and 1999/00, Pearl millet and sorghum utilization based on varieties, Desirable sorghum and pearl millet traits or characteristics, Food security and income shocks, Household investment expenditures, Credit contracted by members of the households in 2008/09, Household perception of welfare changes since the adoption of sorghum and or pearl millet varieties compared to 2008/09 (Only for improved sorghum or millet varieties adopters.

Very preliminary results on 200 households from Jigawa State (major growing pearl millet state in Nigeria) showed the predominance of pearl millet SOSAT C88 produced by more than 42% of farmers. However, the sorghum variety ICSV 111 is produced by about 12 of farmers. Varieties such as ICSV 400 are being dis-adopted due to 2 main reasons including religious limitations and poor yield. Preliminary results showed that farmers in Northern Nigeria are aware of a wide range of sorghum and pearl millet varieties. More than 14 sorghum and 12 pearl millet varieties were known by farmers. Sorghum varieties included ICSV400, ICSV111, SK5912, hybrid varieties (ICSH89002NG, ICSH89009NG, NSSH91001, NSSH910002), and a range of local varieties. About 42% of farmers are aware of modern sorghum varieties with 26% who adopted. The most popular varieties are modern varieties ICSV400 and ICSV111, and local varieties Kaura, Bargozaki and Farafara planted on 8.30%, 7.98%, 25.95%, 9.19% and 5.68% of sorghum growing area respectively. The area planted to improved sorghum varieties is estimated to about 20%.

The major constraints to adoption reported by farmers are seed availability (28.57%), low yield (17.86%), disease problems (10.71%), lack of information on variety management (14.29%) and high requirements for fertilizers (10.71%). In particular the sorghum variety ICSV400 is being constrained its low yield and is also facing a social constraint due to religious beliefs in the Northern part of Nigeria. Farmers growing ICSV400 are associated with beer.

More than 65% of farmers surveyed were aware of improved pearl millet varieties of which 60% are growing those varieties. The most popular varieties are SOSAT-C88 and Ex-Bornou planted by about 36% and 22% of farmers respectively. Improved pearl millet varieties account for 43% of pearl area.

Farmers reported seed availability (15%), low yield (22.50%), low market value (6.50%), late maturity (14.50%) and small size grains (7.50%) to be the major constraints to adoption of modern sorghum varieties.

Special Project Funding:
Data not available

Jupiter Ndjeunga

Intermediate Output Target
Asia
Achievement of Output Target:
100% (Asia)

Participating Countries:
India, China and Thailand

Participating Partners:
ICRISAT, Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad; Marathwada Agricultural University (MAU), Parbhani; Andhra Pradesh Federation of Farmers Association (APFFA), Hyderabad; Krishi Vigyan Kendra (KVK), Beed, JK Agri-Genetics, Hyderabad; Janaki Feeds, Hyderabad. China: Liaoning Academy of Agricultural Sciences, Shenyang, and local partners. Thailand: Field Crops Research Institute (FCRI), Bangkok and local partners.

Objectives:
The project aimed at mobilizing groups of small-scale sorghum and pearl millet farmers in Asia for improving production and productivity by use of improved cultivars of sorghum and pearl millet, improved technologies, through input linkages; bulking and grading of produce, scientific storage and handling practices, and bulk marketing of grain through output linkages.

Methodology:
A systematically planned baseline survey of the project supported villages and the farm families in all project clusters was carried out to establish a benchmark for key indicators such as yields, marketing costs, and other production related costs. An impact assessment survey was carried out in order to look at the cluster-level impact of the project.

Progress/Results:
The main results from the impact assessment study of the CFC-FAO project on improving smallholder livelihoods are presented below:

Region-I, India:
Andhra Pradesh (Palvai and Udityal clusters):
The grain productivity among project farmers showed remarkable improvement in both clusters over baseline and control farmers (106% for pearl millet and 73% for sorghum). This was due to the use of inputs like hybrid/improved cultivar seeds and better production technologies in particular recommended under the project. At the same time, fodder productivity also increased in Udityal and Palvai, though not as significantly as grain yield. Thus, improved seed improved production technology not only yielded more grain compared to local varieties but also increased fodder production.

Output linkage initiatives and increased grain yields as outcomes of the project influenced a shift in the farmers' attitude towards utilization of grain from consumption to commercial purposes. Project interventions opened up for the farmers' opportunities of bulking, direct selling to the poultry industry and off-season sale. This considerably improved the net marketed quantity of grain at the household level in both clusters.

For pearl millet in Palvai cluster gross returns of farmers increased by 170% and net returns several times compared to the baseline. Decomposition of the gross returns indicates that increase in grain yields contributed 44%, grain price 18%, fodder yields 7%, fodder price 9% and rest due to interaction effect. For sorghum gross returns increased by 100% while net returns increased by 220%. Grain yields alone contributed 47% to the increase in gross returns.

Maharashtra (Anjanpur, Rohatwadi and Koke clusters): This included Rohatwadi cluster with pearl millet, Anjanpur and Koke with sorghum as target crop.

Marginal increments in grain productivity were evident in Anjanpur and Rohatwadi clusters over baseline, as farmers were already using improved cultivars, whereas in case of Koke cluster a 67% increment in grain yield was achieved compared to the baseline results reflecting the potential realized through adoption of improved production technologies. Fodder productivity showed only a marginal improvement over baseline and control for all clusters in Maharashtra.

In Anjanpur and Koke, output linkage initiatives changed the pattern of grain utilization. With opportunities of bulking, grading, storage, farmers were selling directly to poultry industries and other alternative end users. However the farmers in Rohatwadi cluster continued to sell pearl millet grain in the local regulated markets as they got better prices. There was significant reduction in the marketing cost due to the project interventions as compared to the baseline and control cases. The output linkage initiatives by the project helped farmers get higher prices for their grain in all the clusters compared to baseline and control results.

Increase in grain and fodder productivity coupled with price increases resulted in increased net returns for project farmers in Anjanpur (118%) and Rohatwadi cluster (63%) over baseline. In Koke cluster higher productivity coupled with higher prices increased the net returns 481% over baseline net returns. In Ananjanpur, Koke and Rohatwadi clusters the price factor was more pronounced in increasing returns than grain yields although grain yields increased by 67% in Koke cluster and 19% in Anjanpur cluster.

Region-II:
China:
In China, where the yields are already high the project intervention had less impacts on yields, but the project farmers consistently recorded a 5% higher yield due to the further improvement of production technology and improved seed. The output linkages that were established under the project reduced the marketing costs to the farmers by 0.015 USD/kg in 2007 and project participants were able to consistently command higher prices.

In 2007, for the participating farmers the sale of total of sorghum grain increased to 273.6, valued at 66,922.6 US$, with mean price of 0.24 US$ per kg. For the non-participants, the average price increased to 0.21 US$ per kg, which is still lower than that of the participants. We also observe that the price obtained by participating farmers is higher than that of non-participating farmers over the past 3 years (2005-2007) indicating that the farmers got the benefits from the project due to improved quality of grain and market linkages.

Thailand:
For farmers in Suphan Buri and Kanchanaburi growing white sorghum yields increased by 40% compared to the baseline, and prices by 48%. Gross income from growing sorghum increased from US$ 114 /ha in 2004 to US$ 237 /ha in 2007 (108%). For red sorghum the commonly cultivated type grain yields increased by 62% compared to the baseline, while prices increased by 32%. Gross income from growing sorghum increased by 160% on an average compared to the baseline.

Any Comments/Explanations:
Project completed and project closing workshop was held at ICRISAT Patancheru: CFC-FAO-ICRISAT Project Final Workshop, ICRISAT Patancheru on 18-20 March, 2009.

The project outputs and impacts were presented at the Regional Round Table Meeting on Commodity Development in Asia, in Nanning, China, held on 17-20 August 2009

P Parthasarathy Rao

Intermediate Output target in 2009: Trends in Adoption of Conservation Farming Practices among Smallholder Farmers in Zimbabwe

Achievement of Output target:
100%

Participating Countries:
Zimbabwe

Participating Partners:
AGRITEX and NGOs in Zimbabwe

Progress/Results:
This project provided a summary of the trends in adoption of conservation farming (CF) technology among smallholder farmers in Zimbabwe. It is based on a study that was carried out in 15 districts where different Non-Governmental Organizations (NGOs) have been promoting CF to vulnerable households for at least three years. The study employed a panel approach where the same farmers who were interviewed in previous surveys since 2007/08 season, were re- interviewed with the objective of assessing CF impacts across time. A total of 416 households were interviewed using a household questionnaire that sought to quantify CF impacts.

The survey results show that the 78.4% of the respondent farmers were initially selected by the NGOs, and were provided with inputs, such as seed and fertilizer. Eleven percent of the interviewed farmers did not practice CF during the 2008/09 cropping season. The relief programs were the main source of inputs with 45.7% of farmers receiving inputs from NGOs. Input support was however limited and farmers also relied on seed from previous harvests kept in their own stock. The unfavorable market conditions that prevailed during the course of the season meant that farmers had limited access to seed at their usual rural outlets. The greater proportion of total CF area was planted to maize (82%), even in the drier areas where maize production is risky. Farmers prefer maize because it is the staple crop and are even reluctant to rotate with legumes.

As expected, farmers obtained higher yields on CF plots than on non-CF plots. Average CF maize yield was 1664 kg/ha compared to 997 kg/ha for non-CF across all 15 districts. In most instances, the CF plots were better managed in terms of timely planting, weeding, and appropriate application of fertilizer. However, the contribution of CF to total household food security requirements was limited due to small plot sizes. CF cereal production contributed to more than 50% of total cereal production in only 3 out of the 15 survey districts.

Different CF components are being practiced at different levels. Labor still remains a major challenge that is limiting the expansion of CF area, with some farmers perceiving CF as a hard way of farming. CF plot size is limited by access to inputs and labor constraints associated with larger CF plots. Male-headed households tended to increase plot sizes over time. Female-headed households may have been more likely to face labor constraints. Winter weeding remains a challenge due to labor and time constraints, with 63% of farmers practicing it. Application of residues is still limited (56%), whereas fertilizer application is largely dependent on access to support. Farmers apply alternative soil fertility amendments such as cattle manure and leaf litter particularly as a replacement to basal fertilizer.

Research should continue to explore different recommendations for different areas as farmers face dynamic agro-ecological and soil environments. CF should not be introduced as a blanket technology for different areas, but should be flexible and adaptable to local conditions. Most extension is being done by NGOs, with the Department of Agricultural Technical and Extension Services' (AGRITEX) role being limited, mostly due to lack of resources. AGRITEX should however play a leading role in spearheading CF uptake and there is need to continue capacity building within AGRITEX and NGOs to sustain CF uptake. There is also need to pursue alternative relief input distribution programs with the voucher-based system being one option. Farmers need to be linked to input markets such as commercial agro-dealers and local retail outlets.

In conclusion, the study recommends that it is vital for policies to support interventions that aim at improving livelihoods and food security for the poor and marginalized communities. The government should play an important role in creating a favorable policy environment that promotes CF sustainability such as in issues related to accessibility of input markets, strengthening extension services, linking farmers to credit facilities, and creation of output markets for the farmers.

Special Project Funding:
International Fund for Agricultural Development (IFAD)

Kizito Mazvimavi

Output 3: Database and new methodologies addressing the impact of bio-physical and social science research developed

Output target 2009 1.3.1 Impact assessment master classes in Asia completed

Achievement of Output Target:
100%

Participating Countries:
Australia, Bangladesh, , China, India, Indonesia, Iraq, Pakistan, Papua New Guinea, The Philippines, Sri Lanka, Thailand, and Vietnam

Objectives:
The primary focus of the Master Class was to provide participants with the knowledge and skills necessary to undertake robust ex ante and ex post economic impact assessments of agricultural R&D and to make them aware of methodological advances in impact assessment and pathway analysis. The requirements for clarity, transparency, and credible evidence in ex-ante and ex-post impact assessment were also covered. The planned outputs of the ten-day Master Class were two-fold. First, to enhance the capacity of the participants to undertake quantitative impact assessment and second, to develop a collaborative bond between the participants themselves, and between the impact groups of ACIAR and ICRISAT and the participants. It is hoped that this will continue into the future. The outputs are intended to lift the participants to a higher skill level through the method of focused teaching. The Crawford Fund seeks to understand and maximize the

impacts and benefits of its investments in training, and especially in its Master Classes, as part of its efforts to support international agricultural research.

Participating Partners:
Kasetsart University, International Cooperation Group Planning and Technical Division, Centre for Policy Dialogue (CPD), Bangladesh Agricultural University, Acting Head of Research Planning and Int'l Cooperation Division of Agricultural Environment Institute (AEI), Sri Lanka Council for Agricultural Research Policy, Guizhou Academy of Agricultural Sciences, Pakistan Agricultural Research Council, Indonesian Center for Agriculture Socio Economic and Policy Studies, Indonesian Agency of Agricultural Research and Development (IAARD), Bogor Agricultural University (IPB) Indonesia, Indonesian Centre for Agricultural Technology Assessment and Development ICATAD, Philippine Institution for Development Studies, Visayas State University (VSU), Philippine Rice Research Institute State Board of Agricultural Research, National Centre for Agricultural Economics and Policy Research (NCAP), CSWCRTI, Central Institute of Fisheries Education Fisheries University, University of Agricultural Sciences , Acharya NG Ranga Agricultural University, International Water Management Institute. Partners involved are from NARES in Bangladesh, Cambodia, China, India, Indonesia, Laos, Nepal, Pakistan, The Philippines, Sri Lanka, Thailand, and Vietnam.

Progress/Results:
The main presenters of the Master Class were Cynthia Bantilan and Debbie Templeton with support from several specialized resource persons. The classes were a mix of theoretical and empirical presentations, hands-on exercises and fun, participatory games. The highlight of this master class was the various group activities of practical sessions which were innovative and make learning fun. These group exercises followed the theoretical sessions on impact models and evaluation, impact pathway analysis, estimating spillover effects and were also tools in good practice to undertake impact assessment. A second innovation was gaining first hand experience through field visits and participatory sessions with the scientists at ICRISAT. The collaborative bonds and the networks created as a result of the sessions and the informal, out-of-classroom activities will definitely strengthen and enrich the future impact assessment collaborative initiatives of ICRISAT, ACIAR and the NARES participants.

The interesting features of the Master Class include a) concepts and tools for agricultural research evaluation and impact assessment, b) imbuing impact culture in R &D organizations, c) a tour of good practice in undertaking impact assessment; d) understanding each participant's experience and role of IA in their organizations; e) participatory exercises; f) practical evaluation exercises; and finally g) a recap at the beginning of each day.

The Master Class program has proven to be an effective means for developing and honing high-level skills of scientists and policy advisers. An interactive approach was taken to most of the exercises. Responsibilities assigned to participants for daily review sessions and for group activities, ensured that each contributed to the program. Time was allocated to group activities that promoted social and cultural exchange, as well as to visits to sights in the Hyderabad area. The Master Class concluded with an evaluation of the class and awarding of certificates to the participants.

At the end of the program, each of the 25 participants received a CD with their presentations, photos and other course material as well as pertinent ICRISAT and ACIAR publications.

Special Project Funding:
The Crawford Fund
Australian Centre for International Agricultural Research (ACIAR)

MCS Bantilan

Output target 2010 1.3.1 Impact pathways approach applied in ICRISAT planning and M&E process for enhancing relevance of R&D interventions in the SAT

Intermediate target output in *2009 Impact Pathways Approach in analysis of ICRISAT IPGs*

Achievement of Output Target:
70%
International agricultural research for development is expected to follow an innovation pathway that starts with problem identification and research, leading to production of outputs that will subsequently be tested, adapted and applied to obtain social and economic value. International research institutes have a mandate to understand what is required in the overall context and identify the major constraints to the improvement of agriculture. With this background, we recognize that IPGs can be developed not only as outputs of upstream research but also as downstream processes through which these outputs are delivered to the clientele. Implementation and interaction among partner scientists, public and private sector organizations, farmers, and other players provides opportunities for institutional learning and change (ILAC).

Participating Countries:
India

Participating Partners:
Implementation of the selected studies will be coordinated by GT-IMPI with the support of ICRISAT Research Committee (all GTLs, Breeders, Socio-economists, Principal Investigators of the respective projects, Directors of ESA and WCA and the DDG) NARS partners and stakeholders.

Progress/Results:
In order to effectively address the complex demands of integrated natural resource management (INRM) a systems approach is required that is both inter-disciplinary and participatory, and covers the full range of the research to development spectrum. On this basis, the case studies on ICRISAT IPGs from downstream research appeal to the impact pathways approach to understand the innovation pathways and determine key lessons learnt through the R for D and Impact continuum. In watersheds development for instance, a key strategic lesson for ICRISAT has been the need for collective action which led to development of the consortium approach that has been adopted by the Indian government as well as other countries in Asia and Africa.

<div align="right">MCS Bantilan</div>

Intermediate target output in 2009: Enhanced the attainment of more research impacts and conduct of impact pathway analysis based on the MTP

Achievement of Output Target:
70%

Participating Countries:
Sub Saharan Africa

Participating Partners:
The intended target output is coordinated by GT-IMPI with the support of ICRISAT Research Committee, NARS and stakeholders.

Progress/Results:
Enhanced the attainment of more research impacts in WCA (increased reach of microdosing/warrantage-inventory credit) and ESA (increased adoption and impacts of chickpea (Ethiopia), improved pigeonpea (Kenya and Tanzania) and groundnut (Malawi).

Western and Central Africa (WCA):
- Additional 30,000 farmers have adopted microdosing and for ESA, new chickpea, pigeonpea and groundnut varieties evaluated and their quality seeds distributed to smallholders and seed producers.
- Scaling up and out of the microdosing technology and warrantage micro-credit system continued with an additional 3000 farmers using the technology through demonstration trials and Farmers Field Schools (FFS).
- Microdosing and warrantage will be further scaled up and out to reach more than half a million farmers in Burkina Faso, Mali and Niger with anticipated funding from AGRA and IFAD.

Eastern and Southern Africa (ESA):
- Farmer participatory variety selection (FPVS) on-farm trials have been conducted for chickpea (Ethiopia), pigeonpea (Kenya, Tanzania and Malawi), and groundnut (Malawi and Tanzania). In each country, 6-7 varieties of each crop have been evaluated and more than 6000 farmers have participated in variety selection and demonstration activities across the four countries.
- Apart from the on-farm trial and the demonstration plots, more than 3 tons of pigeonpea and 7 tons to groundnut seed has been distributed to communities through revolving seed schemes in Kenya, Tanzania and Malawi. Over 3000 smallholder farmers belonging to farmer groups have accessed improved varieties.
- Seed availability remains the major limiting factor for technology uptake. In an effort to address this problem, ICRISAT-ESA with partners has embarked on improving availability of breeder and foundation seed of farmer and market preferred cultivars. About 27 tons of groundnut breeder seed - 19.5 tons (Malawi) and 7.5 tons (Tanzania) - is under production. Similarly, more than 10 tons of pigeonpea breeder seed is under production in Malawi, Tanzania and Kenya. For chickpea, more than 15 tons of breeder seed have been produced in Ethiopia while about 5 tons are under production in Tanzania. In collaboration with the seed companies and small-scale farmers, about 200 ha (about 203 tons expected) and 37 ha (47.5 tons expected) of groundnut foundation seed production has started in Malawi and Tanzania, respectively. For Pigeonpea about 19 ha (28 tons expected) and 14 ha (21 tons expected) is under production in Malawi and Tanzania, respectively. For chickpea, over 26.2 tons of popular varieties (Arerti, Shasho, and Habru) has been produced by small-scale farmers and has been distributed to more than 300 farmers for production of commercial seed.

<div align="right">MCS Bantilan</div>

Intermediate target output in 2009: *Conducted impact pathway analysis in Asia (enhanced utilization of sorghum and pearl millet grains in poultry feed industry); WCA (improved groundnut seeds in Mali, Niger, and Nigeria); and ESA (innovations in pigeonpea and groundnut in the region).*

Achievement of Output Target:
70%
The study was conducted to look and understand pathways that bring about coalitions of institutions, utilization of improved production technologies in India, China and Thailand, and developing and strengthening input supply and marketing chains in Asia. New insights from adoption studies and implications for designing effective impact pathways for the target crops in Africa were identified.

Participating Countries:
Asia
Sub Saharan Africa

Participating Partners:
NARS partners from the participating countries

Progress/Results
Asia: Report submitted and discussed with the Governing Board (GB) looking at coalitions of institutions, utilization of improved production technologies in India, China and Thailand, and developing and strengthening input supply and marketing chains.
- More than 5,000 farmers in India, China and Thailand have planted improved, high yielding sorghum and pearl millet cultivars and practiced integrated nutrient management and integrated pest and disease management. Farmers have benefited by way of higher returns from the project due to utilization of improved cultivars, management practices and bulk marketing. Likewise, they sell their produce in bulk to poultry feed and alcohol manufacturers.
- On developing and strengthening input supply and marketing chains, farmers associations organized under the project were linked to input and credit agencies for bulk purchase of inputs and access to credit. Backward linkages were established with poultry feed

industry and poultry producers. This has reduced the cost of inputs while ensuring quality, reduced credit-processing time, and increased credit utilization at lower interest rates.
- Forward linkages were also established with the alcohol industry for the bulk sale of grain after harvest. This has reduced marketing and transaction costs by 35-40% while ensuring a higher price for grains. In China, an innovative marketing linkage model involving contract farming (linking farmers to alcohol and food industry) gave farmers 15-20% higher income compared to selling outside the contract.

WCA: Report submitted and discussed with the GB featuring enhanced achievement of more impacts in terms of yield gains, lower production cost, and net income gains by adopters and plausible impact pathways.
- The impact pathways of groundnut research for development in Mali, Niger and Nigeria are currently being mapped out. The research and knowledge sharing pathways have been identified and data have been collected.

On the whole, higher yield gains were obtained in Mali (24.06%), Niger (42.95%) and Nigeria (31.48%). Net income gains of farmers over non-adopters were 66% in Mali, 73% in Niger and 111% in Nigeria. The full report will be ready latest by third week of July 2008.

ESA: Report synthesizing the lessons learnt and new insights from adoption studies and implications for designing effective impact pathways for the target crops.
- The adoption studies have provided several useful lessons. First, an important lesson is the fact that many farmers with a desired positive demand for improved varieties did not adopt mainly due to various constraints. Previous adoption erroneously considered these farmers as having zero demand. Our studies using a double hurdle statistical framework showed that past approaches lead to biased conclusions. The key constraints to variety adoption are seed access, information access and credit. In Tanzania, among the 240 households surveyed in 2004, about 34% had adopted new pigeonpea varieties, but 22% could not adopt due to lack of access to improved seeds, about 13% did not adopt due to lack of full information about new varieties. This shows that an additional 45% of the target farmers could have adopted new varieties had access to information and quality seeds improved. Similarly in Uganda, from 945 farmers surveyed in 7 districts in 2006, about 59% adopted new groundnut varieties, about 18% did not adopt due to lack of seed access, and 8% did not adopt due to lack of reliable information, about 6% due to lack of credit to buy seed. This also shows that if these constraints are properly addressed by the national program and NGOs, an additional 32% of the target farmers would have adopted new varieties.
- Second, the overall weakness of the formal and informal seed systems as well as the extension systems for food legumes remain the major limiting factor for technology adoption. Despite efforts to liberalize markets for grain and seed, the commercial seed sector has been very slow to develop, especially for open-pollinated varieties of cereals and legumes where farmers can save their own seed for some years once they gain access to the new varieties. There are also several entry barriers and rigidities that limit the participation of the private sector in seed supply in Africa. This include poor rural infrastructure, free or subsidized seed through relief and recovery programs, rigid requirements for variety registration, restrictions on seed imports, and at times price regulation.
- Third, in cases where seed laws are deficient or quality control systems are weak, seed traders cannot often differentiate quality seed from food grains. Lack of incentives for commercial seed companies means that the public sector and informal seed systems would be required to fill the gap. But the public sector seed agencies are often characterized by high overhead costs and inefficiency while informal seed systems lack capacity to meet seed demand in the desired quantity and quality. Some countries like Tanzania have introduced a semi-formal community based seed system that combines some features of the more flexible informal systems and the regulatory framework of the formal system. This is called quality declared seed (QDS) and relies on truthfully labeled seed produced by trained farmers under the inspection of the regulatory agency and marketed within the community.
- Fourth, there is a need to develop private-public sector partnerships for improving availability of breeder and foundation seed for legumes and strengthening informal seed systems through community based seed production and marketing systems that also involve village level input agro-dealers. Government policies in ESA have often favored food staples like maize and largely neglected the food legumes – vital for the poor both in terms of food security and cash income in the semi-arid areas. There is a need for increased policy advocacy in support of dryland food legumes.

Special Project Funding:
CFC
Bill and Melinda Gates Foundation

P Parthasarathy Rao (Asia), Bekele Shiferaw (ESA)
and Jupiter Ndjeunga (WCA)

Intermediate output target in 2009: *Farmer knowledge and adoption of fertilizer microdosing technology in Zimbabwe*

Achievement of Output Target:
50%
This project looks at the level of knowledge and adoption of micro dosing practices among small holder farmers in semi arid areas of Zimbabwe. The Protracted Relief Program (PRP) through various Non Governmental Organizations (NGOs), since 2002 has been actively involved in distributing fertilizer to vulnerable farmers to help re-establish farming operations These fertilizer distribution programs have been complimented by training on reduced fertilizer application rates, otherwise known as micro dosing. As promotion of fertilizer use continues, it is important to assess the level of farmer knowledge and factors affecting the adoption of micro dosing technology.

Participating Countries:
Zimbabwe

Participating Partners:
AGRITEX and NGOs in Zimbabwe

Progress/Results:
The study covered 12 districts with NGOs funded by PRP namely; Binga, Hwange, Mangwe, Matobo, Tsholotsho, Insiza, Zvishavane, Chivi, Zaka, Chipinge, Mwenezi, and Mutare. Two wards were selected per district. 10 farmers who received fertilizer and micro dosing training were randomly selected per ward.

Three quarters of the farmers interviewed had more than 10 years experience in farming and yet by 1998 only 20% of these farmers had experience in using fertilizer. Close to 50% of the respondents started applying fertilizer to the field crops within the last five years. This coincides with the onset of free fertilizer distribution by NGOs. Close to two-thirds of the farmers frequently applied fertilizer since they adopted the micro dosing practice. However, the consistency in fertilizer use remains variable among recipient farmers with about 19% of the farmers rarely apply fertilizer to their crops, the majority citing fertilizer costs and availability as the main constraints to usage.

The majority of farmers (53.7%) received training on fertilizer use and microdosing directly from NGOs, who in most cases provided relief fertilizer packs. Local AGRITEX staff also actively participated in trainings, accounting for 39.7% of farmers trained. The involvement of Lead Farmers in the promotion of microdosing is still limited, with only 6.4% of farmers receiving advice from Lead Farmers. Microdosing training was conducted by agencies at varying periods with 43% of the respondents claiming to having been trained before November, the onset of the planting season. There are concerns on whether farmers would be able to remember most of the recommended practices when the training was conducted off-season, with no actual demonstrations on farmers' fields. Distribution of pamphlets and posters to complement training on micro dosing is still limited, with only 29.4%, and 14.9% of the farmers having seen pamphlets and posters respectively. The majority of the farmers (84.7%) used the recommended application method of top dressing with either bottle cap (50.2%) or teaspoon (31.9%).

Adoption of micro dosing practice has been influenced by the provision of relief fertilizer packs and associated training by NGOs and AGRITEX. There is still room for improvement in micro dosing promotion as some farmers were unclear about efficient fertilizer use and application methods. Opportunities for improvement include improved extension, continued research, improved market access, and pro active farmer organizations addressing farmers' constraints.

Special Project Funding:
IFAD

Kizito Mazvimavi

Intermediate target output in 2009: *Understanding Partnerships @ ICRISAT for Strategic Impact.*

Achievement of Output Target:
75%
This study formally examines the intricacies of public-private partnerships at ICRISAT in order to learn from experiences on how best to develop strategic partnerships that work and to develop a learning module for ICRISAT staff and partners on "Successful Partnership Management."

Participating Countries:
India and SSA

Participating Partners:
Data not available

Objectives:
How have the partnerships evolved at ICRISAT ? This is in terms of actors and their roles, relationships/ principles of engagement, learning and levels of success. The traditional research paradigm on which the CGIAR centers have operated, is one of strategic research which then gets passed on to national research systems for adaptation and eventual dissemination to farmers. There has always been the expectation that there will be considerable research spillovers from one region to the next. The most recent model put forward for the CGIAR, is to have a few "global centers" together with regional centers. The fact that this model is being proposed, is in response to perceived weaknesses associated with the existing model. ICRISAT has incorporated elements of both approaches at different times in its history. In the early 1990s there was a strong regional element which was then discarded in 1996 only to be partially reinstated. The question that needs to be asked is whether we are clear as an institute which model we are pursuing and how we should realign our research agenda and management structures, among others, to ensure that everybody is clear on the direction we take.

Methodology:
The data and information on strategic partnerships at ICRISAT was collected in two phases. In the first phase, a web based survey using Question Pro was conducted in May 2008 by the KMS unit followed by an email survey in September 2008 by GT-IMPI. This survey was intended for all scientists and staff that have projects (completed and ongoing) implemented through joint efforts with various institutions (i.e. NARES, State Universities, Private Companies, etc,. The web based survey was targeted at 132 scientists based in Asia, ESA and WCA locations.

In the implementation of the second phase, an email survey was conducted by GT-IMPI and KMS, which was more successful. The survey questions were designed to assemble basic information on the purpose, partners, outcomes, duration, benefits, lessons learned and best practices adopted in the PPPs. This survey using the questionnaire was conducted among all scientists in the SAT of Asia and Africa who have projects (completed and on-going) implemented through joint efforts with various collaborators.

Progress/Results:
The study examines public–private partnerships in the light of institutional behavior, and lessons learned, which facilitate/impede the exchange of potentially pro-poor knowledge and technology. The focus is on three elemental/key issues: 1) reasons for forging partnerships, 2) benefits accrued from the public private partnerships and 3) lessons learned from the ongoing partnerships to harness more successful strategic partnerships in future.

Various collaborations engaged by the scientists of the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) were examined, especially those working linkages between and among researchers based at international, regional and national organizations spread across Asia and sub Saharan Africa. Data and information were obtained through an email- based and internet- based survey across all the regional locations of ICRISAT. The resulting analysis provides a characterization of public–private partnerships at ICRISAT and describes the factors that contribute to their success and failure.

These findings are important for developing a learning module on best practices in undertaking strategic partnerships at ICRISAT.

Any Comments:
The web based survey was targeted at 132 scientists based in Asia, ESA and WCA locations. The response rate was very low (13.66 %) due to problems in internet connectivity, loss of files, and inability to save the file.

Special Project Funding:
Nil

R Padmaja , K Kavitha and MCS Bantilan

Output target 2011 1.3.2 New methodologies Impact evaluation methodologies tackling social processes and capacity building, along with lessons learnt from analysis of impact pathways developed and shared with national and sub-regional agricultural systems**.**

Intermediate target output in 2009- Methodology development for documenting network architecture
An intermediary output target under this activity completed in 2009 is the development of methodologies for establishing the network architecture in the six villages under the village-level studies. The details are given under Output 9.

Intermediate target output in 2009- Documenting research evaluation methodologies on assessing policy-oriented research and measuring returns to capacity building

Achievement of Output Target:
100%

Participating Countries:
Global

Participating Partners:
Impact Master Class participants

Objectives:
To gain information as well as document - research evaluation methodologies including assessing policy orientated research and measuring the returns to capacity building.

Methodology:
Participatory exercises were conducted for drawing up impact pathways using the coalition case study as a model case study. This formed the basis for further discussion and enhanced learning on how to do policy orientated research and measuring returns to capacity building.

Progress/Results
While the ultimate goal of agricultural research for development is to improve the living standards of the poor in developing countries, it is recognized that not all research projects result in a practical impact because there is no guarantee that the project results will be taken up. This is because there are special challenges to achieving impact. For example, as impacts generally occur numerous years after the project is finished, researchers have little control over the final processes or steps towards impact. Even in case of adaptive and adoptive research projects, which build on earlier work and have relatively short lag periods, persons or organizations outside the research project are responsible for scaling-up and/our scaling out the new technologies. The pathways to change are complex and can depend on a number of factors such as the institutional, cultural, biophysical and political environment.

Given these complexities, developing an impact pathway provides a pragmatic strategy for tackling the seeming intractability of documenting consequences along the impact pathway. This is because it provides a framework for not only identifying outputs, outcomes and impacts of the research project of interest but also a means of mapping the cause-and-effect linkages along the impact pathway. As such, it can be an important prelude to ex post evaluation as it provides a guide to the major focal points of the analysis, and to data needs and sources. Therefore, even if not required, undertaking an ex post impact assessment within an impact pathway framework helps to increase the likelihood that all intended and unintended, and positive and negative impacts are identified, and where possible quantified.
A practical exercise where the participants 'walked' the impact pathway was undertaken to reinforce the complexities cause-and-effect relationships and the key stakeholders along the pathway.

Impact assessment of capacity building and training: assessment framework : Research on the assessment of capacity building was motivated by the lack of evidence to support the strongly held convictions that improving human capacity is inherently valuable and absolutely necessary for the achievement of development objectives.

Pathways from capacity building to impacts. Capacity-building activities contribute to improved economic, environmental and social outcomes through four main pathways. Individual human capital raises the productivity and hence the earning capacity of the individual, reflected in higher lifetime income. The efficiency of the organization as it captures part of the returns from the individual improvement in productivity, and due to the echo effect improving the productivity of other workers via complementarity—for example, extension of their learning and adding to the local stock of knowledge. This is reflected in improved levels and/or reduced cost of services or outputs delivered by the organization to customers. Innovation in the organization as the culture and mindset changes, new and better ways of doing things are introduced and new products and services are developed. This is reflected in the changes in the services or outputs the organization delivers to customers. Effectiveness of the organization within the policy environment, improving targeting to areas of need, attracting more resources and engaging more effectively on policy, due to the networks and enhanced perceptions of the views of the organization, as well as its competency. This is reflected in the contribution the organization makes to the enabling environment for adoption of the organisation's outputs and enhances the value added of the organization. These 'changes in practice or behaviour' reflect capacity used by the individual and the organization they work for. The potential to utilize capacity depends in part on the capacity that has been built by the training activities. This depends, in turn, on the relevance and quality of the training or other capacity-building activity provided, as well as the degree to which the organization uses the skills, knowledge, networks and other capacity developed by the activities.

The ultimate beneficiaries, apart from individuals who may receive both financial and intrinsic benefits from the training, are the customers of the organisations. For agricultural research and development (R&D) these customers are primarily the farmers and communities in which

they live. Thus, impact is ultimately derived through the delivery of lower-cost and/or better-quality goods and services. Impact can also come through a better enabling environment that enhances farmers' access to resources and markets and allows them to reap the rewards of their own labour.

Mapping to impact: Three types of capacity-building situations are identified, with different implications for the evaluation approach. Gap filling—where the activity fills a gap that enables progress to be made towards a broader set of outputs and outcomes. In this case the capacity built may be sufficient to result in a change in practice or behaviour at the organisational level (as set out above). Integrated—where the training activities are identified as a component in a broader set of technical or other investments. In this case, the capacity-building activity is usually necessary but not by itself sufficient for the desired change in practice or behaviour. Diffuse—where the training activity adds to the stock of human resources but cannot be linked directly with specific change in practice or behaviour. In this case, it is the quantum of capacity built that leads, over time, to changes rather than any one contribution to this capacity.

Special Project Funding:
ICRISAT, ACIAR, Crawford Fund

MCS Bantilan

Output 4: Current agricultural growth trends and future outlooks for the SAT analyzed and shared with key stakeholders

Output target 2009 1.4.1 Global economic outlooks for dryland agriculture including supply, demand, trade and prices for ICRISAT mandate crops

Output target in South Asia

Achievement of Output Target:
50%
Scenarios finalized and run. Consolidation of data and analysis completed

Participating Countries:
Global project

Participating Partners:
ICRISAT, IFPRI, University of Newcastle, Australia

Objectives/Rationale:
To compile and document historical trends in the production, trade and consumption of ICRISAT mandate crops and forecast future trends.

Methodology/Approach:
Compile and analyze secondary data and use the IMPACT WATER model developed in collaboration with IFPRI to forecast future trends in production, trade and consumption.

Progress/Results & Policy Implications:
Area, production and yield data were compiled and analyzed for the ICRISAT mandate crops globally and in those regions that encompass the Semi-Arid Tropics. The regions include Western and Central Africa, Eastern and Southern Africa, and Asia. A few salient results are presented below:

Sorghum:
The global sorghum production has remained stagnant while area has decreased overall during the period 1980 to 2007. Yield and production have shown an increasing trend in the past two years (2006-07). In Africa, both area and production have shown growth since 1990 which have been more pronounced in the past 5 years. The increasing trend for area particularly in WCA, production and yield can be attributed to:
- Increased demand for cereals (food, feed, brewing industry)
- Increased investment in "taking technologies off the shelf" projects increasing improved varieties.

In Asia, area and production have been declining but yield levels have been showing a positive growth for the past five years. In India, both area and production declined in the last two decades, but production has been increasing since 2003 driven by yield increases.

Millet:
Globally, the area under millets has decreased over the years 1980 and 2007, increases in productivity has contributed significantly to the increase in production in the last five years. In WCA there has been a significant increase in area and production, and a moderate increase in productivity, including past five years. The yield increase per ha (especially in the past five years) could be attributed to increased use of improved cultivars and fertilizer (micro-dosing). In India, high fluctuations in area and production are due to rainfall variability and growing pearl millet on marginal lands. Area has declined over the last three years but there is an increasing trend in productivity and production.

Chickpea:
Globally, production and area have been increasing sharply, due to the entry of Canada, Australia and Myanmar as significant producers since the mid-nineties. In Africa, from a low base, area and production have started increasing since the mid-nineties due to ICRISAT initiated legume diversification in ESA in the early nineties. In Asia, productivity and production have shown an increasing trend in the past three decades. Fluctuations in chickpea production are due to the fluctuations in area which is dependent on available soil moisture and rainfall. There have been dynamic changes in the centre of chickpea production in India from the northern part of India to the southern part. There is an increased availability of short duration varieties suitable for warm and dry climates.

Pigeonpea:
Globally, area and production have been increasing while productivity has been relatively stagnant over the years 1980 and 2007. Africa has witnessed area and production increases since 1990 due to productivity gains mainly in Uganda, Tanzania and Kenya. In Asia, area and

production have been increasing since the mid-nineties while productivity remained stagnant. Myanmar is emerging as a lead producer of pigeonpea.

Groundnut in shell:
Production of groundnut is largely concentrated in the Asia and Africa. Production has increased by 2% per annum in the last ten years. There has been a significant increase in productivity over the period 1980-2007. In Africa, there are divergent trends that emerge in groundnut production and yields. In ESA, Mozambique and Zimbabwe together account for more than one third of groundnut area in the ESA but the average yields here are very low (less than 500 kg/ha). In WCA, on the contrary, area, production, and productivity have shown significant increases especially in the last five years and the high yields in this region are largely driven by the yields in Nigeria

Groundnut production in Asia exhibits an increasing trend, mainly driven by productivity increases. China and Vietnam are the main contributors to the increasing trend in production. Area harvested in India follows a declining trend in the period mainly because the crop lost area in the traditional growing areas to other crops. Despite a yield growth of 1% per annum in 1980-2007, production in India barely grew during 1980-2007 due to decreasing area in traditional growing areas. Low productivity can be attributed to cultivation in low and erratic rainfall areas.

Trends in competing crops:
Long term production trends of the important competing crops such as rice, wheat and maize were also examined. The analysis shows that the area, production and yield trends in all crops are increasing both globally and in the SAT regions. In addition to area expansion under these crops, yield increases are also quite significant. Typically, yields of rice and wheat are in excess of 2 tons per hectare globally, compared to 600 kg per hectare for chickpea and pigeonpea.

IMPACT model:
Using the IMPACT WATER model, it is possible to generate the likely changes in production, trade, prices, and consumption of chickpea, pigeonpea, groundnut, and soybean at a country and at aggregated regional and global levels, given technology improvements, climatic conditions, and policy induced changes. The scenarios that were run included increasing the yields of the crops in the major producing countries, simulating droughts in major producing countries, changing trade protection levels for the major exporting countries, and income increases in major consuming countries. The model generates results over a 25 year timeline and can be compared and contrasted with the results of a business-as-usual scenario. Of all the indicators, the net trade position of a country was the one that registered the most change. It was also interesting to note that while changes in any parameters pertaining to India and China (i.e, 25% increase in the yield growth rate in India for chickpeas, trade protection measures in China) had global effects while changes to other countries (i.e., increasing area under chickpea in Australia or increasing trade protection for pigeonpea in Myanmar) had more of a localized effect. World prices of the mandated crops are projected to increase gradually from 2000, peaking in the years 2015 to 2017 and gradually tapering off in 2020.

MCS Bantilan, P Parthsarathy Rao and Pratap Singh Birthal

Output target 2011 1.4.1 Regional outlook (supply, demand, trade, prices) reports of ICRISAT mandate crops

Intermediate output target in 2009 (South Asia)

Achievement of Output Target:
75%
Consolidation of data and analysis completed. Final report nearing completion for mandate legumes (chickpea, pigeonpea and groundnuts).

Participating Countries:
Global project

Participating Partners:
ICRISAT

Objectives:
To compile and document historical trends in the production, trade and consumption of ICRISAT mandate crops and forecast future trends for India.

Methodology:
Compile and analyze secondary data and use the IMPACT WATER model developed in collaboration with IFPRI to forecast future trends in production, trade and consumption

Progress/Results:
Area, production, and trade trends of groundnut, chickpea and pigeonpea were reported in the Archival Report 2008. This year, further analysis and synthesis of the data and further literature searches were carried out on the topics of consumption, utilization, policies and outlooks for the crops. The main findings are as follows:

Groundnut:
Globally, over half of the total groundnut produced is crushed into oil for human consumption or industrial uses, and slightly less than 40 percent is used directly as food, raw or processed into snacks. However, this pattern of utilization varies greatly across regions. In Europe, and North and Central America, more than three-fourths of the available supply is used as food; while in Asia 35% of the available supply is used as food and 55% is crushed into oil.

Use of groundnut, as food as well as manufactured products, has been expanding in most countries in Asia. Between 1981/83 and 2001/03 in China, driven by increased domestic supply, the utilization of groundnut as food increased 3-fold and as processed products 4-fold. In India too utilization of groundnut as food and processed products increased but not as significantly as in China. The pattern of utilization in Asia however did not change much, except in China where the share of processing increased by 7percenttage points during this period.

Groundnut meets 4.5% of the global edible oil demand. Between 1981/83 and 2001/03 global consumption of groundnut oil increased by 65%, from 2.9 to 4.7 million tons. Asia accounts for 69% of the total world consumption of groundnut oil – pretty much the same as its share in production, and it total consumption increased by 66% during this period.

The demand for groundnut (in shell equivalent) in India is expected increase to 8.8 million tons in 2020 from 6.2 million tons in 2000 according to the IMPACT model. However, the production growth is unlikely to catch up the demand growth, forcing the country to be a net importer of 0.70 million tons of groundnut (in-shell equivalent). In contrast, China will be having a small trade surplus (0.71 million tons) despite a rapid increase in demand from 13.1 million tons in 2000 to 22.0 million tons in 2020. Vietnam will also face a small decline in its trade surplus from 93000 tons in 2000 to 75000 tons in 2020. Other countries like Indonesia and Myanmar will be importing more in 2020 than in 2000. On the whole, with business as usual assumptions Asia region will turn from a trade surplus to a trade deficit region, and Africa will have a stronger positive trade balance.

Chickpea:
In 2001/03 of the global chickpea supply nearly three-fourths (5.8 million ton) was used for food, and rest for feed and seed. In proportionate terms uses of chickpea have remained unchanged during the last two decades. Since 1981-83, however, its consumption as food, however, increased by 1.1 million tons in absolute terms.

The pattern of utilization of chickpea varies across regions and countries. In Asia approximately 78 percent of the total chickpea supply is used as food; and the total demand for chickpea as food increased from 4.3 million tons in 1981/83 to 5.1 million tons in 2001/03. In Africa its use as food increased, in absolute as well as proportionate terms. In 2001/03 approximately 84 percent of the total chickpea supply in Africa was used as food, marginally higher than in 1981/83. In Europe, the food demand for chickpea increased, but its share as in the total demand fell drastically to 72 percent in 2001/03. On the other hand, the proportion of the total chickpea supply consumed as food is low in North and Central America where only about one-third of it is used as food. In Oceania chickpea is rarely used for food purpose; and most of the chickpea produced is exported.

Chickpea is also used as animal feed. Globally, 14 percent of the total available chickpea supply in 2001/03 was used as feed, and this proportion did not change much since 1981/83. Use of chickpea as feed is more prominent in North and Central America, and Europe where about 55 percent and 20 percent of the chickpea supply, respectively is used as feed. Further, in North and Central America demand for chickpea as feed more than doubled during the last two decades. In Asia about 13 percent of the total chickpea supply is used as feed, but mainly the byproducts obtained after milling.

The IMPACT model forecasts that India's production is set to increase from 5 million tons in 2000 to nearly 10 million tons in 2020. Despite this India's imports will increase substantially from the 2000 levels owing to increased demand. Increased exports from both Australia and North America are also forecasted. Myanmar's demand for chickpea is forecast to increase as well, and the domestic production will not be sufficient to meet this. Therefore Myanmar's imports will rise, creating a trade deficit of 102 thousand tons in 2020. World prices of chickpeas are projected to increase gradually from 2000, peaking in the years 2015 to 2017 and gradually tapering off in 2020, eventually settling at little over $ 620 per ton (at 2000 prices).

Pigeon pea:
Approximately 85 percent of the global pigeonpea supply is used as food, and 4 percent each goes for processing and animal feed. This pattern of utilization has not undergone any significant change during the last two decades. Since Asia accounts for bulk of the pigeonpea production and consumption the global pattern of utilization is influenced by the changes in the utilization pattern in Asia. The pattern of pigeonpea utilization in Africa is not much different.

There has been a considerable increase in food demand for pigeonpea in the last two decades. Between 1981/83 and 2001/03 the global consumption of pigeonpea increased by 34 percent; from 1.9 million tons to 2.6 million tons. The consumption increased faster in Africa than in Asia. During this period, total consumption of pigeonpea increased by 147% in Africa as compared to 29% in Asia.
In India 88 percent of the available pigeonpea supply is utilized as food, 5% as animal feed and 3% as seed. The demand for pigeonpea, however, has not increased much. Between 1981/83 and 2001/03 the total consumption of pigeonpea increased by 12 percent, and mainly during 1981/83 to 1991/93.
The IMPACT model predicts that. given the current levels of yield growth, per capita income growth and demand structures, Africa is set to increase its exports of pigeonpea as production increases faster than domestic demand there. Pigeonpea production in India is also set to increase from 2.6 million tons in 2000 to 4 million tons in 2020, but the net trade situation is set to worsen due to faster growth in demand. In contrast, the net trade position of Myanmar is set to improve, settling at a trade surplus position. The world price of pigeonpea is set to increase from 2000 to 2020. However, the model indicates that the prices of pigeon pea will grow faster after 2010, eventually settling at $610 per ton in 2020 (at 2000 prices).

<div align="right">MCS Bantilan, P Parthsarathy Rao and Pratap Singh Birthal</div>

Output target in 2009 (ESA)

Achievement of Output Target:
50%
Situation and outlook analyses for targeted legumes

Participating Countries:
Malawi and Ethiopia

Participating Partners:
NARS from Malawi and Ethiopia

Methodology:

The situation and outlook assessments have been completed for all the three legume crops in selected countries: chickpea (Ethiopia), groundnut and pigeonpea (Malawi). There is an ongoing effort to complete a market survey for pigeonpea in Tanzania which may also provide some of the required information for a situation and outlook report on pigeonpea in this country. Data used for this analysis are primarily obtained from existing data at ICRISAT and from secondary sources such as FAOSTAT, published documents and various national reports. The secondary data comprised of aggregate data on global, regional and national production output, data on export and import volumes of targeted crops, global and national price trends over years, and data related to access to seeds. The time series data used ranges from a minimum of 3 years to a maximum of 14 years. A number of statistical tools were employed to analyze, summarize and present the data. For analyzing the historical trends over the years and estimate the growth rate, descriptive statistics are used. The global food projection modeling framework of IMPACT (the International Model for Policy analysis of Agricultural Commodities and Trade) recently calibrated and adapted for policy analysis of dryland crops is applied to examine the future situation for chickpea in Ethiopia and groundnuts and pigeonpea in Malawi. These country sub-sector assessments have been already published in the TL-II website for a wider use. The reports are expected to feed into regional situation and outlook reports that would outline the current production conditions, key socioeconomic and technological constraints and key interventions for unlocking the potential of the targeted legumes in the region.

Progress/Results:

In terms of the projected area and production trends over the 20–year horizon for which the projections are made, the results suggests that chickpea area and production in Ethiopia will show significant growth in the coming years. However in order to leverage the chickpea sub-sector for poverty reduction and food and nutritional security in the country, results suggest that there is a need to design a more flexible and sustainable seed systems that meet the needs of the resource poor farmers. This requires policy makers to open up the seed sector and encourage and assist private seed companies and community seed producer associations by improving access to agri-business development services and empowering cooperatives and village agro-dealers. Results also suggest the need for improving the performance of chickpea value chains by increasing farmer linkages with the industry and exporters, reducing transaction costs and targeting the development and distribution of large-seeded kabuli varieties that offer price premiums in international markets. Ultimately, the competitiveness of smallholder farmers in chickpea production will depend on accessing, adopting and adapting promising varieties and production practices. This will require large-scale demonstration efforts and participatory variety selection in key production environments to identify locally adapted and profitable varieties.

The future outlooks for groundnuts in Malawi seem promising; however, there are a number of constraints that negatively impact on the development of the groundnut sub-sector. The analysis has revealed weaknesses in the current seed systems as well as in the enforcement of quality standards. The technology delivery and the grain marketing systems are underdeveloped, leading to the low use of improved technologies and the production of poor quality of nuts with high levels of aflatoxins that make it unacceptable in the international markets. Although the volumes of groundnut exports remain lower than the levels seen in the late 1980s, the review has shown that Malawi maintains a comparative advantage in groundnut production and competitiveness in exports suggesting that there is scope for increasing groundnut exports once the required quality standards are adhered to. Therefore the findings suggest the need for faster productivity enhancement, strengthening seed delivery systems to reach more farmers and the development of existing value chains.

For pigeonpea in Malawi, historical trends show a rise in harvested area, yield and production. Furthermore, the outlook analysis based on production and exports simulations shows that area, production as well as domestic demand will continue to rise. Nonetheless, there are a number of constraints that negatively impact on the development of the pigeonpea sub-sector. The findings reveal existing structural weaknesses in seed and technology delivery and grain marketing systems, which have an effect on the diffusion and adoption of improved technologies and consequently the on-farm productivity and profitability of this crop. Furthermore, while global demand for pigeonpea continues to rise, there is an increasing pressure on African farmers to benefit from these markets due to intense competition for export markets (mainly India) from Myanmar and other emerging producers, as well as the surging demand for other substitutes. Unless productivity growth and market development help offset these threats, it can severely affect the overall competitiveness for pigeonpea farmers. The findings suggest the need for faster productivity enhancement, strengthening seed delivery systems to reach farmers who continue to rely on low-yielding and disease-susceptible local varieties and development of existing value chains and alternative pigeonpea export markets.

Bekele Shiferaw and Solomon Asfaw

Output target in 2009 (WCA)

Achievement of Output Target:
50%
Situation and outlook analyses for targeted legumes

Participating Countries:
Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, Western Africa, China, India, World

Participating Partners:
ICRISAT, IER, INRAN and IAR

Progress/Results:
During the last 4 decades, West Africa has lost its world groundnut production and export shares. Groundnut production shares declined from 23% to 15% whereas export shares decreased from 55% to 20%. China, the leading producer, has significantly increased its shares from 11% to 41%. Argentina, the leading oil exporter, has more than doubled its world share from 12% to 29%. In addition, imports from other oil seeds have significantly increased in West Africa. Soybean and palm oil imports have more than doubled. However, since 1984, groundnut production in West Africa has been increasing by about 6% annually mainly due to area expansion. Senegal and Nigeria remain among the largest world groundnut producers. Groundnut still remains a major source of employment, income and foreign exchange in

many West African countries. Therefore there is a need to reassess market prospects and highlights opportunities for West Africa to regain to its market shares.

The competitiveness of West African groundnut in the domestic, regional and international markets has been limited by the low productivity, aflatoxin regulations, and stricter grades and standards. Relative prices of groundnut oils are higher in the international markets making these products less competitive compared to oil palms, cotton oil and others oil fruits. There are market niches for confectionary groundnut. Access to this market would require knowledge of market requirements. To regain its competitiveness, groundnut productivity and production has to increase significantly, technologies to reduce aflatoxin contamination have to be promoted and grades and standards satisfied

Lessons learned from these past 2 years
- Partnership will be a major issue in the near future. Our current arrangement is still mostly based on NARES institutions that are operating inefficiently in the region. NARES are understaffed and often with low level of expertise not allowing a meaningful interactions with them. They need to be trained.
- Financial reporting has also been a major bottleneck in the project. There are significant difficulties by partners to report on their financial expenditures because of accounting rigidity in their institutions.
- NARES need to be strengthened in survey design, data collection and analysis, and write-up of the reports. They also need to be trained in monitoring and evaluation.
- There is a need for better targeting in scale and scope.
- Need to look at the groundnut issues along the value chain. During all meetings with partners, the issue keeps coming up because of the past integration between inputs and product markets during the 1980s with the state marketing boards. The challenge is how to re-create those conditions with the private sector?
- Aflatoxin is a significant issue that needs to tackled in the future if one has to significantly develop the groundnut market. Aflatoxin has significantly reduced trade and affects health of the rural poor who depends on groundnut for their livelihood.

The partners NARS economists have shown little interest in contributing to write-up of baseline reports. This activity ended up being an ICRISAT activity entirely.

The market data is more limited and the quality of data may be questionable as many intermediaries are not keen to share their transactions and commercial behavior. Efforts will be made to extract information from the data. Data collected on retailers, rural assemblers, wholesalers based on purchases, sales and transaction costs will be analyzed.

Any Comments/Explanations:
Need to use the impact model to make some projections for the next 20 to 50 years.

Special Project Funding:
Bill and Melinda Gates Foundation
IFAD

<div align="right">Jupiter Ndjeunga</div>

Output 5: Investment and policy options for increasing agricultural productivity and mitigating climatic related shocks identified and shared with key stakeholders.

Output target 2009 1.5.1 Development domains report for southern Africa

Strategic Analysis and Knowledge Support System in Southern Africa (ReSAKSS-SA)

Achievement of Output Target:
80%
ReSAKSS-SA ultimate goal is to contribute towards improving policy and strategic planning and implementation in the agricultural sector. Therefore the primary measure of its value lies in the extent to which policy makers use the information and analyses being generated. Specifically both CAADP and RISDP call for an annual growth rate of 6% in agricultural GDP if agriculture is to play a central role in economic growth, poverty reduction and food security in southern Africa.

Participating Countries:
Three SADC countries—Malawi, Mozambique and Zambia in terms of field research. However, when it comes to capacity strengthening and sharing of research results, 15 countries participate and benefit

Participating Partners:
Universities in the region, International Universities such as Michigan State, National Policy Analysis think tanks, private sector, NARS, etc.

Objectives:
To achieve the above rationale, the countries have committed to investing at least 10% of their national budgets in agriculture under the Maputo Declaration. Part of ReSAKSS-SA work is therefore to monitor and accordingly advise Member States on the progress.

Methodology/Approach:
The process involves collaboration with policy analysts in the Members States essentially following the policy change cycle of Data→Analysis→Dialogue and →Action

Progress/Results & Policy Implications:
Strategic directions in managing the program, overseeing implementation of work plans, reviewing drafts for subsequent publication and overseeing the content of Steering Committee meeting are the major activities carried out. This has resulted in the regional program being rated number one amongst the three in Africa in terms of delivery. The main topics of work have centered on :

- strategic analysis on special topics aiming at providing evidence based analysis to support policy and investment decisions
- capacity strengthening on specific tools of analysis in the policy work
- knowledge management, including the building of website and promotion of its use amongst stakeholders in within ReSAKSS-SA network.

In the course of 2009, the following publications were finalized:

Working papers
- Indicators for monitoring and evaluation of agriculture performance and shared goals in Southern Africa
- Monitoring trends in public spending on agriculture: The case of Malawi.
- Trends and Spatial Distribution of Public Agricultural Spending in Zambia: Implications for Agricultural Productivity Growth
- Potential for Intra-regional Maize Trade in Southern Africa: An analysis of Zambia at Sub-national level
- Assessing Potential Welfare Impacts on Agriculture of a Free Trade Agreement in Southern Africa.

Issue briefs
- Rising Global Food Prices: Policy Challenges and Options for Southern Africa
- Monitoring of Public Spending in Agriculture in Southern Africa
- Recent Trends and Future Prospects for Agricultural Growth, Poverty Reduction and Investment in Southern Africa
- Monitoring trends in public spending on agriculture: The case of Malawi.
- Trends in Agricultural Growth and Performance in Southern Africa
- Contract Farming in Sub-Saharan Africa: Lessons from Cotton on what works under what conditions
- Agricultural Growth Linkages and Market Opportunities in Southern Africa – 250 copies printed – Feb 2009

Conference reports
- Agriculture-led Development in Southern Africa: Strategic Investment Priorities for Halving Hunger and Poverty by 2015

Trend reports
- Recent Trends and Future Prospects for Agricultural Growth, Poverty Reduction and Investment in Southern Africa.

PDF versions of all the ReSAKSS-SA documents that have been printed have all been loaded on the ReSAKSS Africa-wide website (www.resakss.org)

A proposal was developed to move ReSAKSS-SA to Phase II aiming at US $ 3.0 million for three years—2010-2012. Chances are high that funding will be forthcoming but this shall be known by end of January 2010.

Special Project Funding:
The funding was obtained from three key donors—USAID, DFID and SIDA

Isaac Minde

Output target 2010 1.5.2 Constraints, challenges and opportunities for regional cooperation in R&D and alternative regional research and development strategies in southern Africa report

Intermediate output target in 2009

Achievement of Output Target:
Agreement reached on constraints and opportunities facing agriculture in southern Africa. This was agreed on by the agricultural research partners in southern Africa. This will now be followed by drawing up an R&D strategy for southern Africa which is a project to be carried out in 2010.

Participating Countries:
All countries in SADC. All countries of SADC are participating in this project

Participating Partners:
The Directors of Agricultural Research in Southern Africa, Regional Universities, International Universities, SADC and its agricultural related directorates, policy analysis institutions

Objectives/Rationale:
After the disbandment of SACCAR—Southern African Center for Agricultural Research, and after many years of no overaching regional agricultural research forum in the region, there was need to develop an institution that would carry out the functions of former SACCAR. But in order to do this, a need to begin pondering on the current constraints, opportunities and challenges for the region. This is because of the fact that the biophysical, economic, institutional and political and policy landscape has changed considerably over the years.

Methodology/Approach:
The methods involve literature review –so as to be informed of what has been done in the area and in particular the policies and strategies of individual countries—which are fundamental in drawing up a regional strategy for R&D. This was followed by collection of data and information of key variables that were deemed necessary for this process. The next stage was organizing stakeholder dialogues with a view to get some consensus on what are thought to be key constraints, opportunities and challenges—and later on to move to the prioritization exercise.

Progress/Results & Policy Implications:
Results are not yet as this project will continue in 2010.

Publications:
Tools for use in the data collection are still being refined at this stage

Special Project Funding:
USAID has provided initial funding –US $ 500 000 to implement this project

Isaac Minde

Output target 2011 1.5.1 Adaptation strategies and layers of resilience to climatic related shocks in Asia

Intermediate output target in 2009
Project entitled, "Vulnerability to climate change: Adaptation strategies and layers of resilience"

Achievement of Output Target:
50%
The overall objective of the project is to identify and prioritize the sectors most at risk and develop gender equitable agricultural adaptation and mitigation strategies as an integral part of agricultural development in the most vulnerable areas.

Participating Countries:
India, Bangladesh, China, Pakistan, Sri Lanka, Thailand, Vietnam

Participating Partners:
Central Research Institute for Dryland Agriculture in India; Chinese Academy of Agricultural Sciences in People's Republic of China; Council for Agricultural Research and Policy in Sri Lanka; Centre for Policy Dialogue in Bangladesh; Pakistan Agricultural Research Council in Pakistan; Vietnam Academy of Agricultural Sciences in Vietnam; and Chiangmai Field Crops Research Station, Department of Agriculture in Thailand

Objectives:
Expected outputs from the project are:
- Improved understanding of climate variability and adaptation-coping strategies of the rural poor in SAT region
- Best practices and institutional innovations for mitigating the effects of climate change
- Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation

Progress/Results:
As an exemplar to other partner countries, the macro level climatic data analysis especially of rainfall for two states namely, Andhra Pradesh and Maharashtra in India of Semi-Arid Tropics is completed. The meteorological sub-division wise rainfall was analyzed categorizing into various sub rainfall periods. Further, rainfall pattern in districts namely Mahboobnagar and Anantapur in Andhra Pradesh and Sholapur and Akola in Maharashtra was analysed for the period 1971-2007. The technical report on "General climatic characteristics of SAT region of India (Special reference to Andhra Pradesh and Maharashtra States)" in Semi-Arid Tropics (SAT) is completed. The survey to analyse the various adaptive strategies is underway. The annual progress report of the project for the period (May, 2008-April, 2009) is submitted to ADB. Completed outputs in 2009 include: a) ADB semiannual progress report b) Training on sampling plan, climatic data analysis and survey Instrument provided to project partners in collaboration with GT-AES and CRIDA to know the perceptions and adaptation strategies of farmers facing climate change and vulnerability c) Annual planning and review meeting and training workshops on agroclimatic analysis, vulnerability analysis and qualitative analysis conducted d) Pre-testing of farmers' perceptions survey completed and survey in India, China, Thailand, Vietnam and Sri Lanka is ongoing, while in Bangladesh, it is scheduled after rainy season of 2009 for both structured and non-structured questionnaire f) The analysis of the weather parameters and other related facets is completed in India and using the sample of India's results, the other partners are progressing and consolidated report is underway. Harmonized implementation and dissemination plan in this cross-country project is envisioned to mobilize key stakeholders including policymakers in addressing the adaptation strategies and achieve resiliency.

Any Comments/Explanations:
Delay in signing of MoA between EA and IA's has led to delay in funds disbursement, which eventually has shifted the timelines for each activity earmarked in workplan submitted in inception report. The workplan was revised in the recently held annual review and planning meeting and was shared with partners and later submitted to ADB. Except Pakistan, the work plan activities of all the countries are as per schedule. Pakistan team could not be trained inspite of 2 attempts of invitation, one in India and another in Bangkok.

Special Project Funding:
Asian Development Bank (ADB)
In kind contributions from partner organizations.

<div align="right">Naveen P Singh and MCS Bantilan</div>

Intermediate output target in 2009- Farmers Perception on Climate Change in Semi-Arid Tropics Region of India

Achievement of Output Target:
100%.
The report is completed and submitted to School of Rural Management, KIIT University, Bhubaneswar, India, as a requirement of Masters degree.

Participating Countries:
India

Participating Partners:
KIIT University   : Abhinandan Das
ICRISAT   : Naveen P Singh, MCS Bantilan

Objectives:
The main objective of the study is to analyse the actual change in climate change and the perception of the farmers to this changes. The specific objectives are given below
1. To analyze the pattern of climate variability in the semi-arid tropics of India especially, in Maharashtra and Andhra Pradesh villages
2. To find out the farmer's perception on climate variability in the targeted locations

3. To identify the adaptation strategies of the farmer's to cope with climate variability and suggest future action to adapt in climate change

Progress/Results:

The climatic trend of the study area in the Maharashtra and Andhra Pradesh villages has shown a significant decrease in the rainfall with increase the deviation from the prevailing rainy pattern. The maximum and minimum temperature of summer and winter season has also shown an upward trend in the last two decades. The cropping pattern of Andhra Pradesh and Maharashtra has changed considerably from cereal crops except maize towards pulses and other cash crops like sugarcane and cotton. Increase in fertilizer application, irrigated area and market price with change in rainfall has been the probable reasons, which account for the shifting of crops. From the farmer's perception, it is quite notable that most of the farmers perceive the change in climate, increase in the annual temperature and reduced with more erratic rainfall more precisely in the last decade. This led to shift in the irrigation practices due to decrease in the ground water level and drying of wells and tanks. The cropping of the study villages also showed shifting from cereal to non cereal crops. Decrease in rainfall is one of the reasons to change the crop varieties and reduction of cultivable area in the villages. The main coping mechanism adopted by the farmers are migration, taking credits, use previous saving, selling of asset, diversification of livelihood activities including livestock. A sound Governance with proper awareness about soil and water conservation by enhancing the Institutional involvement and further crop improvement research could provide a better way forward.

Special Project Funding:
Asian Development Bank (ADB)
In kind contributions from partner organizations.

Abhinandan Das, Naveen P Singh and MCS Bantilan

Intermediate output target in 2009 – A review of sociological literature on assessment and analysis of past and present adaptation practices by the poor for mitigating the effects of climate change initiated

Achievement of Output Target:
75%.
A review of sociological literature on assessment and analysis of past and present adaptation practices and strategies by the poor and vulnerable is completed and analysis is underway. This work falls under Output 2 of the ADB funded project entitled, "Vulnerability to climate change – adaptation strategies and layers of resilience."

Participating Countries:
This is a desk study and is global in nature but emphasis is on South Asian countries namely India, Bangladesh, Pakistan, Sri Lanka, China, Thailand and Vietnam

Participating Partners:
Indian Institute of Technology-Bombay   : D Parthasarathy
ICRISAT

Progress/Results:
The document based on a review of literature will focus on understanding the issues facing socially vulnerable communities in the context of climate change. It will focus on strategies for climate change adaptation and mitigation that rural communities can use in addressing climate change. The framework of the study will focus on issues around poverty, capacity of the populations at risk, and how to assist vulnerable populations in coping as well as mitigating the effects of climate change. Aside from highlighting the lessons learned from past experience relating to climate change, it will also discuss current research on climate change and social vulnerability.

A Review paper on "Theoretical Approaches to Vulnerability and Adaptative Capacities to Climate Change" was developed.(under draft) . This paper focused on understanding the issues facing socially vulnerable communities in the context of climate change. The objective of the paper is to understand vulnerability as a perception and the adaptation processes and practices through the role of institutions and social –economic factors which can be either boosters or deterrents in enhancing the capacities of individuals or groups to cope with a situation. In doing so the paper looks into concepts of resilience and the relationship that they have both at the ecological and the social level and how the capability approach can play a role in understanding the phenomenon of coping and adaptation. The paper also elucidates the concepts further through examples of different forms of adaptive capacities while examining the different roles of individuals and groups through the capability approach.

Alongside the desk study, qualitative assessments and social analysis using tools (eg. PRAs, wealth ranking, social mapping, case histories, venn diagrams, etc) are being planned to elicit and document best practices and strategies in adapting to climate change including mapping institutional arrangements. Manual on "Social Analysis of Vulnerability to Climate Change and Adaptation Strategies using Qualitative Tools" is developed to serve as an aid for sociologists/researchers to make sure that certain issues are not omitted while collecting information on the perceptions of vulnerability and adaptation to climate change. The manual provides a guide to some of the key qualitative tools and techniques that can be used for gathering perceptions, observing trends and providing analysis with reference to climate change.

Field survey of 6 Villages in Maharashtra and Andhra Pradesh of SAT India is completed to identify perceptions, vulnerability and adaptation to climate change. The aim of carrying out the field survey was to understand & identify perceptions of farmers in the Semi Arid Tropics on climate change and variability, and the vulnerability with regards to the same across different groups. Based on their perceptions the objective was to understand the adaptive capacity of the SAT farmers emerging at the technological, institutional and socio-economic levels.

The sampling method used was purposive sampling to understand and identify the perceptions of farmers in semi arid tropics on climate change and subsequent adaptation practices. Focus group discussions and individual interviews were carried out across large, medium and small farmers, landless labourers and women using semi-structured questionnaires. The information gathered was triangulated by means of narratives, timelines and transect walks. A total of 21 FGDs, and 52 individual interviews were conducted as part of the process. Analysis of the survey using grounded theory is underway.

MCS Bantilan, NP Singh, R Padmaja and Rupsha Banerjee

Intermediate output target in 2009: NARS partners Capacity building: training on Agro-climatic Analysis and Use of Qualitative Tools for Data Collection

Achievement of Output Target:
100%

Participating Countries:
India, China, Bangladesh, Sri Lanka, Pakistan, Thailand and Vietnam

Participating Partners:
Central Research Institute for Dryland Agriculture in India; Chinese Academy of Agricultural Sciences in People's Republic of China; Council for Agricultural Research and Policy in Sri Lanka; Centre for Policy Dialogue in Bangladesh; Pakistan Agricultural Research Council in Pakistan; Vietnam Academy of Agricultural Sciences in Vietnam; and Chiangmai Field Crops Research Station, Department of Agriculture in Thailand

Objectives/Rationale:
A small grants proposal was developed by ICRISAT to build the capacities of the implementation teams and to incorporate into the plans a series of training programs which may be conducted at ICRISAT, CRIDA, Tamil Nadu Agricultural University (TNAU) and in the partner countries. The areas where capacity building training workshops include:
- Analysis of weather data from selected locations, including variability over time;
- Design, methodology and implementation of farm-level surveys in these locations;
- Vulnerability mapping and social indexing with respect to climate change;
- Climate and crop modeling, Geographical Information System (GIS)/remote sensing (RS) applications on climate change, downscaling of the future climate scenario to micro-level situations; and
- Economic modeling, multigoal programming and regression techniques for assessing the impacts of climate change, alternative technology options and policy changes on the economy of vulnerable households in the selected locations.

Methodology:
The two day training workshop from 2-3 October 2009 on Agro-climatic Analysis and use of Qualitative tools for data collection, was organized in Bangkok for all project staff from the 7 partner countries. The workshops were a mix of lectures, presentations, group activities and hand-on exercise.

Progress/Results:
The two day training workshop from 2-3 October 2009 on Agro-climatic Analysis and use of Qualitative tools for data collection, started with a common introduction round of all participants by an exercise of self introduction called 'Who we Are' where each of the participants introduced themselves using the Social, Cultural and Cognitive Functional Lens. The purpose of the exercise was to get an understanding of how perceptions are formed and how they differ from one individual to another. Following this session the two trainings were held simultaneously as parallel sessions with the participants being divided country wise with representation from each of the partner countries for both the workshops. The training on Agro Climatic Analysis started with an overview on the importance of identification of locations for data collection and requirements for analysis.

Training on Weather Data Analysis in Progress : The training was divided into four sessions namely; Database development which comprised of digitization of data in MS XL format along with scrutiny, quality checking and harmonizing data sets. The Weather data Analysis emphasized on converting daily weather data into weekly, monthly, seasonal and annual values along with General statistics mean, SD, CV, rainy days (No of rainy days along with CV) along with Rainfall Analysis- Initial and conditional probabilities and probability of consecutive wet and dry weeks. The section on Water Balance LGP and Drought Analysis dealt with Water balance Analysis & Computation of PET and Indices/ LGP analysis and both its components. The session concluded with Vulnerability Analysis with methods on how to assess vulnerability, dimensions and indicators and quantifications of the impacts of agriculture due to climate change. The resource persons for this training were Dr GGSN Rao and Dr VUM Rao from CRIDA and Dr CRR Ranganathan. At the end of the training it was concluded that the participating members would act as trainers and capacity builders for their respective teams back home.

The stage for the Qualitative training was set by the Introduction of Qualitative Methods, the areas that qualitative research can cover and the importance and use of Qualitative Tools in Climate Change Analysis and data collection. The following sessions on the tools were interactive session where the participants took active part in doing role plays for the tools which can be used with regards to studies on Climate Change. The tools were Focus Group Discussions, Wealth Ranking, Timelines, Social and Resource Maps, Seasonal Calendars, Life History and Narratives and Venn Diagrams. The importance of each of the tools was highlighted in their individual usage as well as they combined use as a method of triangulation along with the sequence that they should be used in. As all the partner countries would be carrying out qualitative surveys using the tools mentioned, a session was dedicated on the use of semi-structured questionnaire along with the sampling method and the rational for the same. The training program closed with the 'Wheel of Wisdom' where it was an interactive and participative session on feedback and clarification of doubts if any, with reference to the two day Qualitative Training Workshop.

The workshop ended with consensus on a certain areas which would act as a point of reference on the way forward:
- With respect to the Qualitative study it was decided that a case study approach would be followed by the Sociologist in the team from the analysis that is generated after the data collection is complete.
- A brief write up on the Grounded Theory along with the steps followed for the same will be provided from the ICRISAT side for better understanding of
- the use of the technique for data analysis.
- Since the team belonged to multidiscipline fields, the multidisciplinary approach shall be maintained though the use of certain tools like the Timelines, Institutional Maps will mandatorily be used among others for the qualitative data collection.
- The participants of the workshop will be instrumental in building capacities of their respective teams on the use of Qualitative tools based on the discussions and knowledge sharing that has taken place over the two day workshop held in Bangkok.

                                                                    MCS Bantilan, NP Singh, R Padmaja and Rupsha Banerjee

Intermediate Output target 2009: Report on Impacts of climate changes on land management in Niger and Nigeria border(WCA)

Achievement of Output Target:
50%
Climate change is increasingly recognized as a worldwide phenomenon that impacts people's livelihoods in many ways. This is especially important in rural area where households are heavily dependent on rainfed agriculture and natural resources in general for their livelihoods. Governments and development partners have largely invested in soil and land management technologies to enhance farmers' adaptation and coping mechanisms in mitigating the negative effects of climates change and variability. This study was conducted with an objective of generating context specific recommendations on how to improve food security and economic development while reducing climate change related risks using sustainable land and water management practices and other strategies.

Participating Countries:
Niger, Nigeria

Participating Partners:
NARS partners from the participating countries

Progress/Results:
A report on "Focus group interviews on impact of climate change in the Tahoua region in Niger and the Sokoto region in Nigeria;' was completed. This includes results from carbon stocks in the 2 regions. This report presents the results of focus group discussions with farmers in the region of Tahoua in Niger where Household level data have also been collected and will be reported in a separate report. The focus group discussions assessed farmers' perception of changes during the last 10 to 30 years with some focus on climate change and their adaptation strategies. The adaptation strategies will include sustainable land management options and land cover and other strategies as well as directly and indirectly related to sustainable land and water use management. The region of Tahoua in Niger represents the agricultural and agro-pastoral zones. In order to better understand the impact of policies and strategies on community response and adaptation to climate change, selected villages had comparable climate changes and livelihoods using matching methods.

The major indicators of climate change reported by farmers include insufficient rainfall and lower yield in 6 out of the 8 villages studied. About half the villages studied reported the drop in water ground level and loss in biodiversity. Reduced soil fertility, high wind and water erosion, decreasing quantity of rainfall and poor rainfall distribution were next reported as important changes in the villages, all consistent with the prediction of reduced and erratic rainfall in semi-arid areas.

Other indicators include deforestation, rapid drying up of wells and mares, increased temperature, reduction of the number of cold months, sand dunes, reduction of the crop cycle, in adaptation of late maturing varieties. Fewer villages mentioned flooding, abrupt end of rainy season, , decreased grazing land and high penetration of hot winds. In some few villages, migration shifted from temporary to being permanent. There were no significant differences between villages with high investment in soil and land management technologies and those with less investment. However differences were found better villages with high access than lo access to markets.

We compared the community perception with the actual rainfall pattern around each village and found limited evidence of community perception on change in the onset of rainfall from June to July.

As a consequence of the changing climate, group of farmers in 2 villages reported changes in surface water quantities such as drying of rivers, ponds, or wells in Tcherassa and Guidan Bayogo. Higher temperatures were reported in Toudou Adaraoua and Elroudou.

Villages reported major changes in the socio-economic and livelihoods. Migration was reported by 6 villages of 8 as a major strategy used to cope with climate change, followed by consumption of non-traditional foods. In half of the villages surveyed, farmers are selling their labor, and are more engaged in vegetable production where water is available. Animal fattening and petty trade have significantly increased as coping strategies. In 3 villages, because of huge migration, women are more involved in cereal production than one would expect. This is a new phenomenon in muslim societies where only men are engaged in pearl millet and sorghum production to feed their families. At best women are engaged in vouandzou or groundnut production. Due to the reduction of grazing area, households are intensifying livestock rearing and there is a market for crop residues. Households are storing or selling crop residues. In most villages, the ratio of small to large ruminants has significantly increased. More women are engaged in livestock fattening and own more livestock.

In most villages, women are also engaged in wood sale, groundnut oil processing and trade, are selling their labor for pearl millet threshing. In 7 out of 8 villages, men are also engaged other activities such as transportation with motor-cycle, camels or carts. Motor-cycle used as means for commercial transportation was reported in the village of Toudou Adaraoua and Elroudou.

A wide range of adaptation strategies were reported by group of farmers in the villages. Farmers report to have introduced new crops, varieties or crop management options. For example, farmers have claimed to have adopted early maturing varieties in response to the reduction of the crop cycle. More manure is now being used. In one village, Toudou Adaraoua, farmers report to have increased significantly the area cultivated to cereals because of poor soil fertility and are now planting pearl millet on dried soils to anticipate on potential early rains. Farmers have also adopted soil and water management options such as the Zai (water micro-catchment) in villages such as Inguira and Elroudou, tree planting in Seyte, Toudou Adaraoua and Inguira and have adopted assisted natural regeneration in villages like Dogon Gona and Inguira.

We compared the number of new improved practices in villages with projects that promote SLM practices with those which don't have such projects. The number of SLM practices adopted recently was higher in villages with projects that support SLM practices. Though these results are based on only few villages, they demonstrate the importance of technical support required to promote SLM practices. We also compared the number of new SLM practices adopted in villages with good access to markets and those with poor market access. In all

districts, villages closer to roads have adopted more SLM practices than those in poor access to markets. This underscores the importance of access to markets and other rural services in enhancing adaptation to climate change.

Carbon stock in selected villages in Niger
A carbon stock inventory was carried out the 7 selected villages in the Tahoua region in Niger to determine the current stock of above ground carbon. The carbon density was computed at the village level and compared across access to market and presence or absence of projects promoting SLWM practices.

The results showed the highest density in Tcherassa Goune and Kenouar where there have been large investments in tree plantation, natural regeneration and forest reserves. However, though one cannot prove this fact, carbon density is lower in villages with low market access than high market access. This is inconsistent with Angelsen and Kamowitz, (1999) and Koto-Same, et al., (1997) who observed more severe deforestation in areas with better market access. However, this can be largely explained by the fact that LM interventions are often done in environments with better access to roads highly correlated to markets.

Comparison of carbon density across the presence or not of SLM investment showed that carbon density is important in villages where there have been significant SLM investment

With regard to land use, carbon density is important on forest, "glacis", slopes and livestock route or corridors. The high carbon density estimated in forests is largely explained by the investment in tree plantation, farmer natural regeneration, and the protected areas. As for "glacis" and slopes, those are areas not exploited in different villages because it is often not easily accessible. Livestock corridors are livestock routes and are not often exploited by the population and received organic manure from cow and small ruminant dunks.

A structured survey of 240 households was collected in the Tahoua region in Niger and 120 households in the Sokoto State in Nigeria.

Conclusions and policy implications:
Review from focus group interactions with farmers revealed high level of knowledge and awareness of climate change and how this phenomenon is affecting livelihoods. All 8 villages involved in study reported to have experienced climate change in many ways in the past 30 years. Responses to climate change and other biophysical and socio-economic changes are related in a complex way. For example, deforestation and tree cutting were the most frequently reported biophysical changes. In the villages, farmers have taken sustainable land and water management (SLM) practices that have been empirically shown to be effective in addressing moisture stress and rainfall variability. Notably, farmers reported to have adopted or enhanced use of mulching, manure and tree planting. In some villages, farmers have adopted new varieties that are drought tolerant. The change has increased vulnerability of the villages to climate change since crop production in the area is riskier than the pastoral livelihoods that villages have practiced for ages. These findings underscore the complex nature of response to climate change and the need to address adaptation by taking holistic approach.

Villages were well aware of the importance of irrigation as an adaptation strategy. In half the villages, vegetable gardening is a major coping strategy. In some villages such as Tcherassa Goune, the government has invested in large irrigation perimeters where farmers could grow a wide range of crops at low risk because of water availability. In other villages such as Toudou Adaraoua, Eroudou,Guidan Bahago, there are large water ponds from which farmer draw water for irrigation or they dig wells to water vegetables. This has proven to be an effective adaptation strategy whereby farmers recognized the reduction in migration due to this opportunity. Government continued investment in supporting villages better catch, conserve and use water should be warranted. Currently the government of Niger and donors are engaged in a large investment project in building small and large scale irrigation schemes as an adaptation strategy to drought.

Improved crop varieties are good tools for adaptation to climate change. In almost all the villages, the adoption of early maturing drought tolerant crop varieties was as one of the adaptation strategy. Governments, research institutes and development planners have invested in the development of early maturing and drought tolerant varieties. However, poor seed delivery schemes have limited access to uptake of those varieties despite more than US$45 million invested in building up seed systems in Niger. There is to redesign such schemes and focus on those that are institutionally more sustainable.

Our above claims are largely based on focus group discussion and offer interesting community insights, perceptions on adaptation to climate change. However, our study bears weaknesses that are likely to be corrected with household data.

Special Project Funding:
Data not available

Jupiter Ndjeunga

Output 6: Strategies for increasing competitiveness through identifying preferred market traits and introducing quality control systems to meet social, food safety and environmental standards for dryland crops established and promoted

Priority 5B: Making international and domestic markets work for the poor

Priority 5B, Specific goal 1: Enhanced livelihoods and competitiveness for smallholder producers and food safety for consumers influenced by changes in national and international markets

Priority 5B Specific goal 2: Improved marketing environment for smallholders by improving the efficiency of domestic markets

Output target 2009 1.6.1 Preferred market traits identified for selected tradable legumes in three regions (ESA, WCA and Asia), livestock (in southern Africa) and dryland cereals in WCA region

Intermediate output target in 2009 (Asia)

Achievement of Output Target:
50%
Information on preferred traits will provide useful feedback to the breeders and extension workers, making dissemination of cultivars easier. Further detailed information on market-preferred traits will aid in priority development and to better understand technology uptake

constraints. This will progressively inform technology design and adaptation and facilitate scaling-up of identified and promising options to the wider impact target domains beyond the pilot areas.

Participating Countries:
India

Participating Partners:
ICRISAT; University of Agriculture Sciences, Bangalore; University of Agriculture Sciences; Dharwad; Punjabrao Krishi Vishwavidyalaya (PKVK), Akola; Tamil Nadu Agricultural University, (TNAU) Coimbatore; Acharya NG Ranga Agricultural University, Hyderabad

Methodology:
Market surveys conducted in important trading centers of groundnut, pigeonpea and chickpea to determine average flow of goods and peak and lean seasons. Interviews with farmers, traders, wholesalers, processors and consumers were carried out in order to gauge preferred traits for the targeted crops and the important bottlenecks for in the marketing system. Data was cleaned and further analyzed.

Progress/Results:
Groundnut:
Data on the preferred traits of groundnut were collected from different actors along the value chain, such as farmers and consumers, and for fodder usage. A survey to gauge farmer preferences was administered in three important groundnut markets in the project area—Raichur, Chitradurga, and Tamil Nadu. The data was analyzed using Garrett ranking technique and premium price analysis. Overall the farmer preferences did not vary much over the different project locations. On the production side high yields, short duration, drought resistance, and pest resistance were ranked as the most important traits. On the consumption side, better taste and longer keeping quality were the traits that were ranked the highest. The Garrett scores for attributes of fodder quality revealed that quantity of fodder, palatability and durability were the most important factors influencing the farmer's decision of seed selection. From the marketing perspective, the price that the produce gets was revealed as the most important trait. Grain size and higher demand for the seed followed next.

In another section of the survey farmers were asked to state their willingness to pay for certain desirable traits in any new cultivars that hypothetically would be introduced. This was done in order to gauge the price premiums that the farmers would be willing to pay for their preferred traits and to assess their price sensitivity.

Chickpea:
Data on the preferred traits and the most common production constraints in the cultivation of chickpea were collected from important markets in Kurnool and Prakasam districts of Andhra Pradesh and Dharwad and Gulbarga districts in Karnataka. The cultivar *Annigheri* is a popular variety in both states. The most significant constraints that were stated were low yields, poor seed quality and high seed cost, lack of information on suitable varieties, non-availability of required variety, and a high incidence of pod borer pests. There was little variation in the preferences of the actors along the value chain between the states. These preferences are presented below:
Farmers
- High yield
- Drought resistance
- Short duration

Commission agents
- Bigger grain size
- Cleanliness and uniformity
- Better taste

Traders
- High recovery rate
- Colour
- Better taste

Processors
- Uniformity
- Bigger grain size
- Cleanliness

Pigeonpea:
Data on the preferred traits and the most common production constraints in the cultivation of pigeonpea were collected from important markets in Ranga Reddy and Mahabubnagar districts of Andhra Pradesh and Akola district in Maharashtra. The ruling varieties differed in both the project states with *Maruti* ruling in Maharashtra while *Asha* was the most popular cultivar in Andhra Pradesh. The most significant production constraints that were cited were low yields, poor seed quality, and lack of information on suitable varieties. The preferences elicited from the different actors along the supply chain are as follows:
Farmers
- High yield
- Drought resistance
- Short duration

Commission agents
- Bigger grain size
- Cleanliness
- Better taste

Processors
- Cleanliness
- Pest and disease free
- Uniformity of grain

P Parthsarathy Rao and MCS Bantilan

Intermediate output target in 2009(ESA)

Achievement of Output Target:
50%
Identify preferred market traits for selected legumes

Participating Countries:
Ethiopia, Kenya, Malawi, Tanzania

Methodology:
Baseline survey methodologies were applied

Progress/Results:
In Ethiopia, we asked the sampled chickpea farmers to rank their preferred traits for chickpea varieties using local varieties as a reference group. The scores are coded from very poor (coded as 1) to very good/excellent (coded as 5), which suggest the direct relationship between the rank and the importance of the variety in terms of specific traits. The preferred traits for chickpea varieties by gender were recorded. The overall score for *chefe* variety is the highest for both male and female chickpea farmers followed by *ejere* types. When we examine based on specific traits, female chickpea farmers prefer *arerti* variety for their taste and high price in the market whereas male farmers prefer the same variety for high price and grain yield. *Shasho* variety is highly preferred for their high price in the market, grain size and grain cooler both by male and female farmers. Male and female chickpea farmers tend to have different preference for *chefe* variety. Male farmers prefer *chefe* for their grain color and size while female farmers prefer for their high price in the market, grain size and low cost of production. The preferred traits for *ejere* variety by both male and female farmers are high price in the market, grain size and grain color. Generally kabuli varieties are highly preferred for their high economic return in addition to their grain color and size. Characteristics of *worku* variety favored by male farmers include good taste and uniformity in maturity while female farmers prefer for good taste, grain color and high price in the market.

In Malawi, farmers were asked to provide information on variety preference and preferred traits for groundnuts and pigeonpea. The ranking was done by using the local variety as a reference point. The ranking was done using a scale of 1-5. The codes for the rankings were as follows: 1=very good; 2=poor; 3=Fair/average; 4= Good; 5=Very good /excellent. The results rankings on preferred traits are presented in Table 9-6. Among groundnut varieties, Chalimbana 2005 is the most preferred variety with the highest overall ranking of 4.2. CG7 is the most preferred variety with an overall ranking of 4.1. The other most preferred varieties include Chalimbana, ICGV-90704, and Manipitar. For the high highly ranked varieties (Chalimbana 2005 and CG7), they are mainly preferred for their high yielding and early maturing traits.

Among pigeonpea varieties, Mthawaju*ni* and ICEAP040 are the most preferred varieties with overall rankings of 4.3 and 4.1, respectively. ICPL945 and local pigeonpea are ranked last with an overall ranking of 3.8 each. The findings further indicate that most highly preferred varieties are liked because they exhibit three key traits; high yielding, early maturity and short time of cooking. Interestingly, Mthawaju*ni*, considered as a local variety, is highly preferred for its high yield, as well as its early maturity and its shorter cooking time, Consistent with this notion, Jones et al. (2002) reports that Malawian exporters are faced with supply constraints in that there is an insufficient production of large and white seeded pigeonpea preferred by the export market (Jones et al. 2002) due to the low adoption of white seeded varieties such as ICEAP00040 by farmers. ICEAP00040 is the second most preferred by farmers, largely for its high yielding traits, which suggests that there is wide scope for promoting its adoption by farmers.

Participating Partners:
NARS from Malawi and Ethiopia

Bekele Shiferaw and Solomon Asfaw

Intermediate output target in 2009(WCA)Farmers, and market preferred traits reflecting gender dimensions

Achievement of Output Target:
75%
To identify farmers' preferences for groundnut traits

Participating Countries:
Mali, Niger, Nigeria

Participating Partners:
IAR, IER, and INRAN

Methodology:
We evaluate farmers' preference for different groundnut varieties' characteristics using a random utility-based choice experiment and ordered probit analyses. Data were collected through a structured panelist survey administered at 6 project sites in the Dosso region in Western Niger, 6 project sites in Northern Nigeria and 4 project sites in Mali.

Mali: Data collection on 4 PVS sites with 75 panelists (Kayes and Kita) and analysis completed. Preliminary results available. Full report being written by IER economist and breeders.

Niger: Data collected on 5 PVS sites with 117 panelists (22 in Doula, 23 in Guidan Gaba, 29 Koma beri, 10 in Tanda and 33 in Wassangou) and 6 varieties (J11, ICGV9346, 55-437, TS 32-1, Fleur 11, RRB). Data analysis completed and preliminary results available.

Nigeria: Data collected in 6 PVS sites with 155 panelists (24 Batsari, 31 in Birnin Kudu, 18 in Charanchi, 32 in Durkin Tofa, 30 in Kaugama and 20 in Rona. Data analysis completed and preliminary results available. Report currently developed partners

In Niger, the preference survey was conducted in the villages- project sites Doula, Guidan Gaba, Koma Beri, Tanda and Wassangou. Six varieties were used mainly RRB, J11, Fleur 11, ICG9346, TS32-1 and 55-437 as a check. A total 114 panelists participated at harvest of which 25% were women. In Nigeria, 155 panelists all men participated in the Jigawa, Kano and Katsina states and six varieties were used in the test mainly SAMNUT21, SAMNUT22, SAMNUT 23, ICIAR19AT, ICIAR6AT and ICIAR7B. In Mali, A total of 74 panelists were involved in the regions of Koulikoro and Kolokani of which 60% of women. Six varieties were also used in the test including ICG 86124, ICG (FDRS)4, Fleur 11, JL 24, ICG 86015.

Progress/Results:
Preferences were estimated for various plant and seed traits from various varieties. In Niger, results showed that the resistance to diseases, green color of leaves, and high number of pods, bec, reddish grain color, and pod yields were the major characteristics preferred by farmers. In Mali, early maturity, high number of pods, the large sized pods, pod filling, pod yields, reticulation and strangulation were the main traits sought by farmers. In Nigeria, high plant vigor, early maturity, type of port, number of pods, high sized pods, high pod yield and high haulm yield were found to be the most significant characteristics sought by panelists.

There were however no differences based on gender in Mali and Niger or other socio-economic characteristics such as age, ethnic group, level of education and wealth. Women are not involved in groundnut production in the project sites. Therefore, they were not included in the survey. These characteristics should be accounted for when designing or selecting groundnut varieties likely to be preferred by groundnut farmers. The results have bearing in research priority settings.

Any Comments/Explanations:
Preferences for other actors along the value chain have not been investigated.

Special Project Funding:
Bill and Melinda Gates Foundation.

Jupiter Ndjeunga

Intermediate output target in 2009(South Asia) Chickpea production trends and marketing value chain analysis in Andhra Pradesh

Achievement of Output Target:
100%.
The report is completed and submitted to School of Rural Management, KIIT University, Bhubaneswar, India, as a requirement of Masters degree

Participating Countries:
India

Participating Partners:
School of Rural Management, KIIT University   : Jeevan Kumar B
ICRISAT   : P Parthasarathy Rao, MCS Bantilan

Rationale:
The objectives of this study are to understand chickpea marketing systems and the constraints that exist along various links in the value chain. There is a lack of empirical data and information needed to facilitate formulation of strategies to strengthen chickpea value chain and to increase its competitiveness on small farms. A detailed analysis of the value chain is therefore needed to understand the various factors which will improve the value chain of the crop.

Objectives:
This study employs a value chain approach and provides an overview of the chickpea subsector in Andhra Pradesh. It examines the factors that affect the chickpea production, value addition, marketing and utilization of the crop in Andhra Pradesh. This study is to identify the existing chickpea marketing channels.
Specifically, the objectives of the study are:
• Document global and regional trends in chickpea area, production and productivity
• Understand the structure of chickpea markets in Andhra Pradesh.
• Map the value chains and quantify the marketing and transactions costs
• Identify the interventions that strengthen the chickpea marketing channels.

Methodology:
Using secondary data, the overall trends in global and regional area, production and productivity were tracked.
A value chain is a sequence of steps involved in the process of production to market delivery of a product. It provides a means of understanding relationships between business, methods for increasing efficiency, and ways to enable business to increase productivity and add value. Value chain approaches are a vehicle for linking small business to markets (Webber). For this study we adopt a broader concept of a value chain to assess the structure and functioning of all the actors along the chain till final product and try identifying the key constraints and weak linkages that determine the overall competitiveness of chickpea. Therefore the strict definition of value chains is not adopted and we use the term market chains and supply chains interchangeably with value chains.

The study undertook a detailed review of literature and analysis of secondary data. The secondary data was collected from the FAOSTAT, Directorate of Economics and Statistics and Director General of Commercial Intelligence and Statistics.

Primary data was collected from 85 marketing channel participants in Andhra Pradesh using detailed questionnaires administered in one-on-one interviews. These participants include farmers, village traders, commission agents, brokers, traders, dhal millers, flour millers,

wholesalers and retailers. These participants were from the second largest chickpea producing district in the AP, Prakasham District: Ongole, Addanki, Uppugundoor and Pamidipadu. Only representative and readily available respondents were purposively selected for the interviews.

Marketing costs were taken to include both transaction costs and standard marketing costs example transport, loading and unloading. Measurable transaction costs include the costs of finding a buyer/ seller and costs of the negotiating prices.

Progress/Results:
Chickpea (Cicer arietinum L.) is an annual crop widely cultivate in semi arid tropics. It is one of the most important pulse crops in India. There are two types of chickpea grown, Desi and Kabuli chickpea. Almost every part of the chickpea crop has commercial value and is most commonly used as dal, followed by whole grain and flour. This study uses a value chain analysis approach to identify the market channels and value additional at different stages of Chickpea marketing in Andhra Pradesh.

Chickpea is mainly grown a rabi crop (post-rainy season) in Andhra Pradesh. It is usually cultivated without irrigation and with minimal inputs. Area under chickpea cultivation has increased from 45 thousand ha in the year 1980 to 394 thousand ha in the year 2005. Kurnool and Prakasham are the largest chickpea producing districts. The present study was conducted in Prakasham district. Due to the widening gap between prices of Desi and Kabuli chickpea farmers are shifting from Desi to Kabuli chickpea in recent years.

Chickpea crop in the Andhra Pradesh is marketed either in the whole grain form or in Dal form or as Futana. Desi chickpea marketed as whole grain Dal and Flour; while Kabuli chickpea is marketed only as whole grain. Usually the kabuli type chickpeas are exported to either north Indian states or other countries. The demand for the Kabuli chickpea in north Indian states is gradually increasing. The processors produce the Dal and Futana and market through prevailing marketing channels. The Indian Government has implemented the export ban on pulses and zero per cent import duty. Due to this policy, imported Desi chickpea is available at lower price than domestically grown desi chickpea.

Presently farmers in Ongole district are relying on village traders and sell their produce and end up getting a lower price. To get better price farmers can form cooperatives to market their produce directly to processors and exports to other regions in India. Govt. should setup a platform to bring the producers and traders at one place so that farmers will get better price.

Special Project Funding:
Bill and Melinda Gates Foundation

Jeevan Kumar B, P Parthasarathy Rao and MCS Bantilan

Intermediate output target in 2009 Value Chain Analysis of Groundnut crop in Andhra Pradesh

Achievement of Output Target:
100%.
The report is completed and submitted to School of Rural Management, KIIT University, Bhubaneswar, India, as a requirement of Masters degree.

Participating Countries:
India

Participating Partners:
School of Rural Management, KIIT University   : Ananth Raj G
ICRISAT   : P Parthasarathy Rao, MCS Bantilan

Rationale:
This study employs a value chain approach and provides a critical overview of the groundnut subsector in Andhra Pradesh. It examines the demand side factors that affect the groundnut production, value addition, marketing and trade and utilization in Andhra Pradesh. The paper transcends the usual subsector analysis to identify the existing groundnut value chains and assess the postharvest aspects affecting the flow of groundnut along the various value chains. It is based on a empirical study that analyzed the marketing aspects and opportunities facing the groundnut industry.

Objectives
The specific objectives of the study are:
   •   Understand the Structure, conduct and performance of Groundnut Markets in Andhra Pradesh
   •   Map the Value Chains and identify the factors that affect local and global competitiveness of the crop
   •   Identify priority interventions that strengthen value chains and facilitate commercialization to harness the full potential of the groundnut subsector

Methodology:
In this study we adopt a broader concept of a value chain to assess the structure and functioning of all the actors along the chain till final product and try identifying the key constraints and weak linkages that determine the overall competitiveness of the groundnut subsector. We deal with marketing conditions where linkages among the players are underdeveloped, and asymmetric information and mistrust are pervasive.

Therefore, the strict definition of value chains is not adopted and we use the term market chains interchangeably with value chains.

Empirical methods:
The study entailed a detailed review of literature together with collation and analysis of secondary data. The secondary data comprised of FAO aggregate data on national output, data on export volumes of Groundnut from India obtained from various published documents and district level production data from major groundnut producing regions in AP.

Information from these secondary sources was augmented with collection and analysis of post farm level marketing data. The post farm level data included information from market survey conducted on 111 value chain actors in Andhra Pradesh in 2009. These value chain actors included farmers, commission agents, brokers, traders, oil millers, solvent extraction unit owners, oil wholesalers and retailers. These value chain actors were from 6 large groundnut markets in AP: Mehbubnagar District: Gadwal, Jedcherla, Kurnool District: Kurnool, Adoni and Anantpur District. Due to difficulties associated with ascertaining the total population of each category of market intermediaries, only representative and convenient respondents were purposively selected for the interviews.

Progress/Results:
Adoni, Gadwal and Jedcherla are some of the biggest groundnut markets in AP. Almost 85% of the produce from 40-50 villages is brought by the farmers to these market yards. Commission agents in these market yards usually facilitate the sale of produce by inviting the traders and oil millers to the bidding process.

In the bidding process the traders and oil millers usually assign prices to the produce depending the various characteristics. All the bids are then taken to the market yard officials who then announce the highest bidder. Most of the traders and millers from local area and traders from Maharashtra and Tamil Nadu participate in this process.

Most of the produce in the 90s was usually bought by the oil millers or by traders who decortify and sell it to the oil millers. However due to the high level of integration with the Mumbai markets and participation of traders from Maharashtra the utilization of produce has shifted toward confectionary purpose in these markets.

Due to premiums attached in the confectionary trade most of the traders now prefer selling their decortified produce to the Maharashtra market. This has resulted in increase of the prices at the farmers end. On the other hand, the oil millers have not been able to buy the high quality produce since the prevailing prices are well above the parity prices. This has resulted in oil millers shifting towards trading for confectionary markets or shifting to crushing of other crops like sunflower and soyabean. These markets have also seen most of the local oil milling units shut down in the last 4 years.

Adoni which once was regarded as an oil capital for Andhra Pradesh now imports oil from Maharashtra and Gujarat.

The price variation in all these markets was markedly observed from 2000 onwards. Also the prices have increased significantly from 2005-06 onwards. While it is a good sign for the groundnut cultivating farmers, the oil millers are increasingly facing some hard times in business and it's possible that some more millers will be shutting down their units in future. The acceptance of the produce from these markets by the confectionary has had significant impact on the prices of the farmers from 2005-06 onwards.

The trading and price determination has also seen significant changes in these markets due to its integration with export and Mumbai markets. While shelling percentage was considered the most important factor for determining the price, the count per ounce which is the price determination factor for exporters is now being practiced while buying the produce at the farmers end.

Kurnool Market:
Kurnool Market is known to be one of the most important places for oil in India. It still has the largest number of oil millers connected to the market in AP. Though confectionary trade in these markets have also increased in recent times, its impact has not been as significant as some of other big groundnut markets. Oil millers still remain the largest buyers of the produce in this market.
Almost 90% of the produce by all farmers from around 50 villages is brought to this market. Though large quantities of groundnut are brought in Kharif, the rabi season has also started seeing an increase in the groundnut arrivals in the past few years. The commission agents usually charge 2% as commission from farmers in this market.
Since the confectionary traders are not major players in this market. Shelling percentage and moisture content are the major price determining factors in this market. There is an oil millers association in this market which plays a major role in trading of the produce.
The rise in prices has mainly been due to the drastic fall in the arrivals of the groundnut. It suggests that there is a decrease in the area and yield of groundnut in the villages surrounding the market. Lack of sufficient arrivals is one of the reasons behind confectionary traders not preferring the Kurnool market.

Ananth Raj, P Parthasarathy Rao and MCS Bantilan

Intermediate output target 2009: *Report on the value chain networks of groundnuts in Mali with aflatoxin contamination is completed.*

Achievement of Output Target:
100%

Participating Countries:
Mali

Participating Partners:
NARS partners from the participating countries

Objectives:
To identify critical points along the value chain that need to be monitored for Aflatoxin levels and to identify policy and institutional hindrances to the value chain efficiency as well as the business service providers available to value chain actors.

Methodology:
The competitiveness of Malian groundnut in the domestic, regional and international markets has been limited by the low productivity, competing oils, aflatoxin regulations, and stricter grades and standards. To regain its competitiveness, groundnut productivity and production has to increase significantly, technologies to reduce Aflatoxin contamination have to be promoted and grades and standards satisfied.

There are currently a range of detection measures to assess the level of aflatoxin contamination and a range of pre- and post-harvest Aflatoxin control strategies available to prevent Aflatoxin contamination. However, the extent of uptake of these technologies and the constraints limiting its utilization are unknown. The cost efficiency of the control measures will depend on the critical points where the demand for these measures is high. There is therefore a need to assess and evaluate the potential critical points where Aflatoxin is very high. This can be done by mapping the groundnut market. The groundnut market map will allow identifying actors along the value chain, the relationship between them and factors determining market efficiency. It also helps identify constraints in the policy and institutional environment that limit the efficiency of the groundnut market as well as access and availability of support services (such as input supplies, market information, and financial services…etc) by value chain actors.

In order to attain the objective, groundnut market will be mapped and focus group interviewed will be carried out with stakeholders in the enabling environment, the value chain actors and the business and extension services.

The Groundnut Market Map
The Market Map is made up of three inter-linked components:
- Enabling environment (infrastructure and policies, institutions and processes that shape the market environment);
- Value chain actors; and,
- Service providers (Input supplies e.g. seeds, fertilizers, aflatoxin control technologies; Market information e.g. prices, trends, buyers, suppliers; financial services e.g. credit, savings or insurance; transport services e.g. for grain purchasing; Quality assurance - monitoring and accreditation the business development or extension services that support the value chains' operations)

Value chain actors who actually form the chain (i.e. transact the main product) are supported by business development and extension services from other enterprises and support organizations (e.g. seed suppliers, artisans and intermediaries). There is an on-going need for chain actors to access services of different types, both market and technical.

Focus group and key resource persons interviews
In order to identify actors along the value chain, and understand the functional relationship between actors, focus groups interviews were conducted with farmers-producers in the 2 major groundnut growing areas in Mali: the cercles of Kolokani and Kita. In each circle, 2 villages were selected based on road accessibility (poor and good road accessibility). In the Kolokani circle, the villages of Siddo (good road access) and Koulikoroni (Poor road access) were selected. The villages of Keniekola (good road access) and Douri (poor road access) were selected in the circle of Kita. In addition, in each market in the circle, a group of traders were interviewed and value chain was mapped at local level. Individual interviews were carried out with wholesalers in the Oueloefebougou and Bagadadji markets in bamako.

Preliminary results:
The enabling environment: The enabling environment is weak in Mali. At the national level, there are no policies or institutions setting up standards and norms related to Aflatoxin levels in the local or regional markets. As a result, quality insurance institutions are lacking. Because of lack of awareness and knowledge of aflatoxin hazards, the Ministry of Commerce and Industries and the Ministry of Health supposedly responsible for setting such institutions have failed to institutionalize aflatoxin as a major health issue or a major constraint to trade. Even if norms and standards were developed and available, their enforcement will be weak. Tax and tariff regimes that could regulate the flow of good quality groundnut seed are non-existent.

Value chain actors and linkages between actors: Value chain actors include farmers- as primary producers, rural and urban assemblers, urban and rural retailers, small, medium and large processors, rural and urban wholesalers and exporters, rural and urban consumers and exporters.
   a) Farmers producers: Groundnut is traded locally through rural assemblers, or sold to rural retailers or direct sale in the nearest semi-urban market such as Kolokani or Kita. Groundnut is stored in different forms: granaries treated or non-treated, or in small warehouses without any special treatment. Groundnut is often not dried enough (high humidity) or warehouse contain high humidity to induce the development of aflatoxin. This makes granary a critical point to monitor.
   b) Assemblers: There are 2 types of collectors: rural and urban. Rural collectors are provided cash by rural wholesalers to purchase groundnut in the villages. This is assembled at a semi-urban location and then sold to urban wholesalers. Collectors do not have warehouses and are acting as middlemen.
   c) Rural wholesalers: They supply finance to rural collectors to purchase groundnut in the village. They then bulk groundnut and sold to urban wholesalers or processors. Groundnut is stored between 3 to 4 months.
   d) Urban wholesalers: The urban wholesalers are the end of the chain and are often also groundnut exporters. They supply groundnut to medium-scale processors. They set up groundnut prices. The urban wholesalers store groundnut up to 1 year maximum in poorly maintained and ventilated warehouse. There, the level of aflatoxin is very high.
   e) Small, medium and large processors: There are few medium processors who processed mainly into oil and paste. Similarly groundnut is not stored for long i.e. Less than 3 months.

Business services: Almost all value chain actors have little access to business services such as financial services, market information, and limited access to inputs such as improved seed, fertilizers and pesticides. In addition, producers are poorly organized and coordinated to collectively sell their produce and thus increase their bargaining power with traders. Value chain actors are poorly linked with each other's and with the market. Though, they have their local grades and standards, these are not suitable to enforce the supply of high quality seed in the market.
Conclusions and follow-up: These are very preliminary results. A separate report is being prepared to this effect. In addition, this study should be extended to the Kayes region, which is another site for this project.

Jupiter Ndjeunga

Output target 2010 1.6.1 Policy options for establishing quality-based agricultural marketing systems for selected legumes, livestock and cereals identified and communicated to policy makers and partners

Intermediate output target in 2009: *Test and evaluate alternative livestock product marketing systems and alternative input delivery systems*

Achievement of Output Target:
90%
Livestock is the most important income source for farmers in semi-arid southern Africa. However, existing markets are largely informal, with poorly developed infrastructure, inputs and services, resulting in high transaction costs and increased risks along the value chain. Although appropriate technologies to increase production exist, farmers without access to markets often have little or no incentive to invest in these. As a result, livestock productivity remains low, and income opportunities are not captured. We believe that access to improved markets will provide farmers with the incentive to invest in increased production, with benefits to the resource-poor and commercializing farmers. We have therefore followed a more integrated approach by investigating challenges from production to consumption along a value chain, while also addressing policy and institutional factors affecting livestock production.

Participating Countries:
Mozambique, Namibia and Zimbabwe

Participating Partners:
See under Special Project Funding

Methodology:
The study combines the results from baseline surveys, IP reports and preliminary VCA to characterize the current status quo and potentials for the development of livestock markets and input delivery systems.

Progress/Results:
The results document a strong motivation towards commercializing livestock in all three countries:
- While most farmers are highly dependent on generating cash from livestock sales, markets are very poorly developed in Mozambique and in Zimbabwe. Although markets in Namibia are much better developed, there are still challenges with the number of animals communities are able to supply to markets.
- Main challenges with regards to markets revolve around: access to information, i.e. when and where markets will take place; how prices are determined and what is required to obtain better prices.
- Auctions are a very good way of selling off livestock, but many farmers do not understand the system and are therefore hesitant to participate. In certain areas, livestock numbers do not warrant the time and effort for buyers to attend, resulting in low number of buyers and in reduced competition and therefore also reduced prices. Auctions were successfully established in Gwanda district in Zimbabwe where buyers are solicited to attend, where the demand for goats are high and the supply from farmers are significant. According to local government statistics in 2009 the established cattle auctions in Gwanda district turned over US$ 940,000. The newly established goat auctions at a project site turned over US$ 50,000.
- In areas where supply is limited, and therefore does not warrant many buyers to attend, the "permit system" as developed in Namibia is an excellent option. Here, buyers 'tender' their services through local authorities and advertise prices offered long before the day of sales. Prices are normally offered per kilogram of live carcass and segregated between different grades, ages, sex and whether animals are intact or castrated.
- From the analysis during this study it is clear that inputs are seriously limited and access is complicated through distances required to travel to input markets, lack of information and support services to communicate the required information. It is strongly recommended to facilitate the partnerships that will enable input suppliers to make their services (with regards to information and products) available at the point of sale. Preliminary information clearly illustrates farmers' preparedness to purchase inputs at the point where animals are sold. Providing inputs at the market place will create the incentive for further investments in production.
- Government support services are dwindling as a result of limited resources, lack of skilled and experienced personnel. It is envisaged that this role could be played by the private sector. Should small-scale farmers engage in increased procurement of inputs, the private sector may just well provide these services where it is to their benefit, i.e. at the marketplace where potential buyers are concentrated and with cash in hand.

Special Project Funding:
- LILI markets: In Mozambique ILRI and Mozambique Agricultural Research Institute (IIAM), in Namibia Namibian National Farmers Union (NNFU), in Zimbabwe Department of Agricultural Research for Development/Matopos Research Station.
- EU/ORAP: Organisation for Rural Associations for Progress (ORAP), The Netherlands Development Organization (SNV), Department for Livestock production and Development (DLPD), Department of Agricultural Research for Development/Matopos Research Station

Sabine Homann Kee-Tui

Output 7: Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted

Output target 2009 1.7.1 Innovative arrangements for better coordination of production, access to inputs and services, and output marketing (for selected legumes (ESA), cereals (Asia) and ruminants in ESA) along the value chain for reducing transaction costs identified and communicated

Intermediate output target in 2009: *Innovation Platforms for improving farmers access to livestock markets and technologies*

Achievement of Output Target:
90% in the LILI markets project, 50% in the EU/ORAP project.

In the context of poor economic performance, increasing food insecurity and poverty in southern Africa, crop-livestock systems represent an important opportunity to contribute to renewed agricultural growth and benefit small-scale farmers. We have developed a novel approach using IPs to place technology and market development in context based on common interests and strong partnerships between private and public sectors. We facilitate IPs to strengthen the dialogue between the main local players in the value chain: farmers, market agents, input suppliers, and the research and development fraternity. The IPs identify opportunities and constraints in both production and marketing. The process is galvanized through discussions on market requirements, followed by an analysis of existing production strategies. It will improve communication between key players in the value chain and information sharing between key role players. This guides strategies which will result in more efficient value chain operations and increases livestock production and competitiveness of farmers. This also builds local capacity, thereby increasing food security and income growth while supporting sustainable impact pathways.

Participating Countries:
Mozambique, Namibia, Zimbabwe

Participating Partners:
See special project funding

Methodology:
The projects invest in facilitating the implementation of IPs at locations with different potentials for commercially oriented livestock production. Baseline surveys and VCA are used to identify the key stakeholders, their linkages and activities and measure performances and transaction costs. The results from baseline analysis and VCA inform the IP in search of solutions to locally defined opportunities and constraints. The projects use the results and experiences from the IP implementation process to design the IP/VCA development tool.

Progress/Results:
The LILI: Markets project has facilitated IPs at two pilot sites each in Mozambique, Namibia and Zimbabwe, and the EU/ORAP project has scaled out four more IPs in Zimbabwe. The IPs brought together key stakeholders in the livestock value chains. They created linkages and improved communication between the key stakeholders, and built a base for partnerships between public and private actors. The IPs identified opportunities and constraints that are most pertinent to enhance the productivity and competitiveness in the livestock sector. They then selected priority technologies and interventions, and support mechanisms. They defined roles and responsibilities in driving this process further. The IPs also encouraged the establishment and strengthening of farmer associations for cooperative learning and input procurement and they linked farmers with competent suppliers of information and inputs.

The IP process has addressed various challenges and allowed several communities and associated value chains to increase the efficiency of their business. This has taken different forms and initiatives, according to area-specific conditions and partnerships. The IPs have engendered a sense of 'ownership' among farmers, support services and other value chain players at the various locations.
- In Mapai, Mozambique, the IP identified the absence of a slaughter house as greatest constraint. Bureaucratic issues and human negligence had delayed the construction of a slaughter house. The IP initiated a dialogue between local government and support organizations to finalize the construction.
- In Tete, Mozambique, the IP prioritized controlling livestock movement and sales through introducing a new branding system and licensing livestock for transport.
- In Hoachanas, Namibia, the IP has mobilized a commercial input supply cooperative to set up a veterinary outlet that supplies inputs, information and services to farmers, and thereby enables farmers to increase commercial offtake.
- In Omatjete, Namibia, the IP has opted to test cattle auctions as alternative market channels to the existing permit sales, using the sale facilities run by the local farmers' association. Farmers expect to gain from more competitive market scenarios.
- In Gwanda, Zimbabwe, the IP has identified lack of competitive markets and transparent price setting as key constraint to obtaining higher incomes from goats. A number of predominantly public actors supported the establishment of auction facilities and services. The local government has realized higher revenues and committed to support similar infrastructure in other areas.
- In Tsholotsho, Zimbabwe, the IP has addressed the institutional constraints that hamper formal cattle sales. The brought decision makers together with those from areas where markets are functional to engage them in a process of learning and correcting the institutional constraints.

Policy gaps and inconsistencies were identified at the different locations and for various levels in the value chain. A policy briefing note was designed that addresses policy makers to provide an enabling framework for partnerships between public and private sectors.

Special Project Funding:
- LILI: Markets: In Mozambique ILRI and Mozambique Agricultural Research Institute (IIAM), in Namibia Namibian National Farmers Union (NNFU), in Zimbabwe Department of Agricultural Research for Development/Matopos Research Station.
- EU/ORAP: Organization for Rural Associations for Progress (ORAP), The Netherlands Development Organization (SNV), Department for Livestock production and Development (DLPD), Department of Agricultural Research for Development/Matopos Research Station

<div align="right">Sabine Homann Kee-Tui</div>

Intermediate output target in 2009 : (ESA) Innovations for improving legume markets
    a) Innovations for improving legume markets
    b) Promising marketing options to reduce transaction costs

Achievement of Output Target:
75%
The baseline surveys are conducted to elicit information at the grass root level for the targeted legumes in the selected locations.

Participating Countries:
Kenya, Ethiopia, Malawi

Participating Partners:
NARS partners and farmers unions in the participating countries

Progress/Results:
Significant progress has been made with regard to this activity. The analysis of baseline household survey data and community surveys in three target counties – Kenya, Ethiopia and Malawi – was completed. The report to present the key findings from these studies is currently being written.

In Kenya, household survey data on pigeonpea from Mbeere and Makueni districts has been analyzed and results indicate that about 88% of households cultivated some pigeonpea. However, only 24% of them grew improved pigeonpea varieties. Most farmers used recycled seed from own savings. Neighboring farmers and government extension workers are the major sources of agricultural information for the farmers. While non-farm income continues to be the main source of cash income for households in this area, the importance of pigeonpea is growing as new and more productive varieties are being made available. With regard to utilization of pigeonpea, results indicate that about 75% of the pigeonpea is consumed on farm.

In addition to pigeonpea, the team also examined data collected from a 2007 survey (from another legume project) to examine the conditions for groundnut production in western Kenya. The data on groundnut production and marketing collected from Homabay, Siaya and Teso districts was analyzed and a draft report developed with the leadership of KARI. The analysis highlighted the current status of groundnut production, processing, utilization, and marketing. The results show that pests and disease infestations were the major constraints to groundnut productivity. Nevertheless, the majority of households (76%) reported that they produced enough groundnuts to meet their personal consumption requirements, while a few farmers reported selling part of the groundnuts produced. Groundnut is sold through a number of channels – fellow farmers, local traders, brokers, and through farmer groups and farmer cooperatives. In general more farmers from Homabay district (81.4%) reported selling some groundnut than farmers from other districts.

Collective action was found to be advantageous to farmers in many ways. About 46% of farmers reported that they marketed groundnuts through collective action groups. This facilitated timely delivery of produce as well as timely receipt of payments by farmers. However, farmer groups seem to have problems while competing with private traders, especially in offering good prices to members. The draft report is under review by team members and a final report is expected to be ready during the second half of 2009.

In Ethiopia, analysis of data from the baseline survey has been completed and writing of the report is underway. In addition, consultation meetings with stakeholders involved in chickpea marketing were held and preliminary results from baseline data analysis were presented at the annual review and planning meeting held during June 4-5, 2009, at Dreamland Hotel, Debre Zeit, Ethiopia. The results from the baseline survey indicate that about a third of farmers grow the new kabuli type chickpeas while about 53% grow the traditional desi type chickpea. Chickpea is mainly produced for markets – 70-80% of the chickpea produced is marketed. About 40-45% of farmers reported that they grew improved chickpea, mainly of Shasho, Arerti, and Ejere varieties. The demand for new varieties is high but limited by lack of seed, information, and land constraints. Government extension and other farmers are the main sources of information on variety and markets for kabuli chickpea. Credit access is limited to just 26% of farmers (for seed) and about 78% of farmers (for fertilizer). About 80% of chickpea farmers sell part of the chickpea produced. Farmers seem to prefer selling to traders than to cooperatives. Gender differences in income exist but not so much in variety choice.

In Malawi, the analysis of baseline survey data is completed and a baseline report is being developed. Results show that about 55% of households grow groundnuts, and 40% grow pigeonpea. Current levels of adoption are about 10% for improved pigeonpea varieties (ICEAP 040 and ICPL 9145) and about 30% for improved groundnut varieties. Demand for new varieties is high but limited by low availability of seed and lack of access to credit – only 16% got credit even though 70% needed it. The government extension system and other farmers are the main sources of variety information for both groundnuts and pigeonpea. About 67% and 57% of pigeonpea and groundnuts produced, respectively, are consumed on farm. About 60% of groundnut farmers sell some groundnut, but the amount sold ranges between 30-50% of the yield. About 50% of pigeonpea farmers sell some pigeonpea, but they sell only about 30% of the production. Most farmers actually sell groundnuts and pigeonpea to rural assemblers even though they prefer selling directly to exporters and urban traders. Gender differences exist in the crop choice – about 48% of female-headed households grow pigeonpea compared to 38% for male-headed households.

In Tanzania, a baseline survey was completed from November 2008 to January 2009 in the four target districts: Arumeru, Karatu, Babati, and Kondoa. Data cleaning has been completed and analysis and report writing are planned for the coming season. The baseline will help to better understand existing conditions on pigeonpea, chickpea and groundnut varieties, yield levels, returns, seed supply systems, market participation, sources of market and agronomic information. Furthermore, at the time of reporting initial preparations were underway for legume market research in the target districts to identify, design, and test institutional innovations to reduce transactions costs.

Several initiatives are being implemented to identify promising options to reduce transaction costs for legume markets. The situational analyses of the chickpea sub-sector in Ethiopia, the pigeonpea sub-sector in Kenya, the groundnut and pigeonpea sub-sectors in Malawi have been completed and reports reviewed by stakeholders in readiness for publication and wider dissemination. In Kenya, preparations are underway for market research to identify, design and test institutional innovations to reduce transactional costs for groundnut. The questionnaires and other survey instruments have been developed, but will be pre-tested before the commencement of the survey in August 2009. In Ethiopia, agreements were made with partners (farmer unions, such as Adama-Lume, Erer and Kesem) to facilitate farmers' sale of their produce to the primary cooperatives of the unions.

Any Comments/Explanations:
While no major problems were reported in project countries, farmers complain of market volatility and market price fluctuations, high marketing costs, and lack of information in understanding markets and commodity chains

No major problems were reported except for Ethiopia where Kesem union was found to be too weak to provide market outlets for chickpea farmers. Efforts are being made to increase the participation of exporters and other private traders to buy directly from organized farmers.

Bekele Shiferaw and Solomon Asfaw

Intermediate output target in 2009(Asia)
Achievement of Output Target:
100% (for cereals in Asia)

Participating Countries:
India, Thailand, China

Participating Partners:
ICRISAT, Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad; Marthwada Agricultural University (MAU), Parbhani; Andhra Pradesh Federation of Farmers Association (APFFA), Hyderabad; Krishi Vigyan Kendra (KVK), Beed, JK Agri-Genetics, Hyderabad; Janaki Feeds, Hyderabad. China: Liaoning Academy of Agricultural Sciences, Shenyang, and local partners. Thailand: Field Crops Research Institute (FCRI), Bangkok and local partners.

Progress/Results:
Two papers were drafted for publication based on the results of the project looking at the coalition approach for poultry feed in Asia. These include: i. Innovative market linkages and building human capital; and ii. Contract Farming model in China. A brief summary of the papers is presented below.

Paper on Innovative market linkages and building human capital: The majority of the farmers in the sorghum and pearl millet cluster villages under the CFC-FAO-ICRISAT project on promoting sorghum and pearl millet for poultry feed is constituted by small and marginal farmers. These farmers have to deal with poor infrastructure, agricultural development services and poor awareness about improved production technologies and face difficulties in accessing formal credit and markets. The above constraints were overcome through developing and integration of human and social capital - capacities, knowledge , skills , values and network of the small-scale farmers, Women Self Help Groups (SHGs) in enhancing production, harvesting, bulking , storage , and capacity to negotiate prices with end users for grain marketing.

The Coalition Approach of the project was helpful to the farmers for secure and equitable access to some of the resources such as technology, credit/finance and other services as well as to markets. Negotiations through farmers association and collective bargaining enabled small-scale farmers in all project cluster villages to reap higher returns on their produce.

For involvement of women farmer groups two models were developed and tested for their meaningful involvement in project activities. One was to involve the SHGs in seed distribution of improved cultivars and second SHG's play the role of pledge financing for farmer stored grain in the cluster godown.

Paper on Contract Farming model in China: The Contract Farming model specified the roles and responsibilities of the public sector (SRI) and private sector (seed, oil, food, and alcohol industries) members involved in the contract with the farmers. The formal contracts are between the farmer and the private sector. The public sector liaises with the private sector to provide improved seed and package of practises. The contracts have enabled small scale farmers to respond to new opportunities and increase their production and income levels through better markets. The other benefits to the farmers in this model are 1. Farmers get extra income about 58 USD/ha from selling glumes to Sorghum Pigment Industry 2. Get 5-10% discount on seed price. 3. get 5% of discount on fertilizer price. 4. Less seed usage per ha (17% decrease) 5. Optimum fertilizer usage per ha (20-25% reduction).

Special Project Funding:
CFC/FAO (no cost extension)

P Parthasarathy Rao

Output 8: Policies and strategies that enhance agricultural diversification into high value products (e.g., legumes, livestock, biofuels, vegetables, etc) to harness emerging demand opportunities and facilitate agribusiness enterprises developed and promoted

Output target 2009 1.8.1 Research report on economic feasibility of diversification using legumes and livestock (ESA) completed

Intermediate output target in 2009: Research document and tools developed for the project on optimizing livelihood and environmental benefits from crop residues in smallholder crop-livestock systems in sub-Saharan Africa and South Asia: regional case studies

Achievement of Output Target:
75%
Crop residues are a strategic production component in smallholder farming systems with the multiple uses as animal feed, construction material, cooking fuel, and mulch. Mixed crop-livestock systems are very dynamic and are evolving rapidly in response to external drivers such as demographic pressure, development of urban markets and increased demand for crop-livestock products, climate variability and change. In addition, the recent interest for bio-fuel production exacerbates further the pressure on biomass in production systems.

Participating Countries:
Malawi, Mozambique, Zimbabwe

Participating Partners:
See Special Project Funding

Objectives:
This study aims at better understanding the tradeoffs in crop residue uses in cereal-based systems in southern Africa. The study contributes to a global study, with other regional research sites in West and East Africa, and India. The major tradeoff in most systems is the short-term benefits of using crop residues to feed livestock versus leaving the crop residues in the field to improve soil productivity (nutrient balance, erosion control, soil health).

Methodology:
The study combines village level surveys and household questionnaires with bio-physical modeling. The key research questions are:
  1. What determines the decisions about crop residue use?

2. What is the impact of those decisions on livelihood and environmental implications?
3. What are the technology, institutional and policy options that would enhance livelihood and environmental benefits?
4. Can key opportunities for enhancing/protecting benefits of crop residue use (sale, on-farm feeding…) be identified by assessing the drivers (markets, emerging technologies…) for their specific use and value?

Progress/Results:
A presentation on drivers and trends in smallholder crop livestock systems of southern Africa has been held at the SLP harmonization workshop.

Any Comments/Explanations:
So far we have developed a project document, sampling strategy and draft research tools.

Special Project Funding:
Optimizing livelihood and environmental benefits from crop residues in smallholder crop-livestock systems in sub-Saharan Africa and South Asia: regional case study Southern Africa (CGIAR / SLP, ILRI, and In Mozambique ILRI and Mozambiquean Agricultural Research Institute (IIAM), in Malawi Bunda agricultural college, in Zimbabwe Department of Agricultural Research for Development/Matopos Research Station.

Sabine Homann Kee-Tui

Output target 2010 1.8.1 Research report on economic feasibility of diversification into high value products with emphasis on biofuels (ESA, Asia) and vegetables (WCA) completed

Intermediate output target in 2009: Research report entitled," Economic feasibility of producing bioethanol from sweet sorghum feedstock in east Africa" drafted for review.

Achievement of Output Target:
80%
The growing demand for energy, volatile global oil markets and global warming have presented the world with the challenge of searching for alternative cheaper and less polluting sources of energy. Biofuels which emit fewer pollutants present an opportunity for reduced dependency on global oil markets.

Participating Countries:
Ethiopia, Kenya, Tanzania, Uganda and Mozambique

Participating Partners:
NARS partners from the participating countries

Objectives:
The study was undertaken with the aim of:
▪ assessing the current status of biofuels in ESA,
▪ evaluating the economic feasibility of producing bioethanol using sweet sorghum as feedstock and its competitiveness relative to other feedstocks,
▪ assessing the tradeoffs with food security and environment, and
▪ outlining policy and regulatory systems required for harnessing bioethanol as fuel

Methodology/Approach:
This study discusses the energy situation in Eastern and Southern Africa (ESA) using five countries in the region as examples. These are Ethiopia, Kenya, Tanzania, Uganda and Mozambique. The aim of the discussion is to build a case for adoption of bioenergy in a region where most of the energy consumed is from biomass (fuelwood, charcoal, dung etc.). It is believed that adoption of bioenergy will have multiple dividends including easing pressure on forests, saving the countries' foreign exchange, improving rural communities' incomes as well as reduced carbon emissions to the atmosphere.

Progress/Results & Policy Implications:
Biomass (wood and charcoal) accounts for about 70 percent of domestic energy consumption in ESA countries a factor which is straining forest resources in the region. Further, the growing demand for energy, volatile global oil markets and concerns about global warming/climate change have presented the ESA region and the world with the challenge of searching for alternative cheaper and less polluting sources of energy. One such alternative are biofuels which emit fewer pollutants compared to conventional petroleum products. Global production of biofuels has doubled in the last five years and will likely double again in the next few years. However, production of biofuels in the ESA region is limited. Countries in ESA region should therefore take advantage of this projected growth because they have favorable climates for growing biomass such as sugarcane, sweet sorghum, coconut etc.

Production of bioethanol in the region will have additional benefits which include: a) savings on foreign currency through import substitution; b) checking environmental problems caused by rapidly increasing traffic and use of petroleum-based products; c) expansion of income generation base particularly in the rural areas; and d) expansion of employment generation, including self employment, particularly in the rural areas where levels of poverty are the highest. Despite the enumerated advantages, it is necessary to carry out economic and financial analyses to determine whether it is economically feasible to produce biofuels in the region. Using sweet sorghum feedstock and Kenya as case studies, the study was conducted to determine the economic attractiveness of biofuel production using hitherto non-conventional feedstocks.

Economic and financial analysis shows that it is feasible to produce bioethanol from sweet sorghum. Presently, the main feedstock used in the region is sugarcane or its byproduct—molasses. In the absence of these two, the use of sweet sorghum as an alternative feedstock has been shown to be economically feasible. In addition, sweet sorghum has an advantage for taking shorter periods to mature and is more drought-tolerant compared to sugarcane. However, the development of biofuel production in the region, including sweet sorghum bioethanol, is hampered by weak or non-existent policy framework to stimulate investments. The required policies on the relationship

between biofuels and agriculture, blending mandates, tax and tariffs, standards, and research and development are not clearly defined in many countries in ESA

Special Project Funding:
IFAD

<div align="right">Bekele Shiferaw</div>

Intermediate output target in 2009: Biofuels in Asia

Achievement of Output Target:
25%
The primary goals of the project Value Chain Model for bio-ethanol production from sweet sorghum in rain-fed areas through collective action and partnership are to empower the farmers to take advantage of new market opportunities and supply the feed stocks in large quantities on regular scale to the industrial sector. To these ends, an innovative Ethanol Value Chain Model involving collective action and partnership of all stakeholders in the value chain is proposed encompassing the establishment of decentralized crushing units in the cluster villages, supply of inputs, technical backstopping and market linkages.

Participating Countries:
India

Participating Partners:
ICRISAT, NRCS, CRIDA, IICT, ILRI, SVVU and Rusni Distilleries

Objectives:
1. Assess economic competitiveness of sweet sorghum as a feedstock for bio-ethanol with sugarcane molasses and grain
2. Economics of sweet sorghum cultivation vis-à-vis competing crops.
3. Economic assessment of decentralized crushing unit (established at Ibrahimbad) for crushing sweet sorghum and production of syrup from sweet sorghum

Methodology/Approach:
Comparative economic analysis is carried out to assess the competitiveness of sweet sorghum in relation to competing crops at Ibrahimbad, Andhra Pradesh.
Ex-post and break-even analysis is carried out to evaluate the economic feasibility of the unit.

Progress/Results:
Some of the major findings of the study are presented below:

Cost of Cultivation of Sweet sorghum and its competing crops.
Among rain-fed crops in Ibrahimbad village of Andhra Pradesh sole crops of maize and sorghum and intercrop of maize-red gram, sorghum-red gram were the competing crops with sweet sorghum for cultivation. Among irrigated crops, paddy and sugarcane were the major crops cultivated.

In rainy season 2008 total cost of cultivating sweet sorghum was Rs. 15,804 / ha while that for competing crops like maize it was 12,363 / ha and Rs. 17,010 / ha for maize-red gram intercrop. Land preparation and composting with 26 per cent was the highest component of cost of cultivation of sweet sorghum followed by harvesting and threshing activity with 22 per cent. Among resources utilized for cultivation of sweet sorghum, human labor with 56 per cent was the highest resource component followed by bullock labour with 19 per cent.

Net Returns of Sweet Sorghum Cultivation and its competing crops.
Net returns of Rs. 6,490/ ha (excluding family labour) obtained from sweet sorghum was the highest among rain-fed competing crops in Ibrahimbad. Returns realized from sorghum & red gram intercrop was the next highest followed by maize- red gram intercrop and sole maize. Among the irrigated crops returns realized from cultivating sugarcane was the highest across all rain-fed and irrigated crops followed by paddy.

Sweet Sorghum Syrup Production from Decentralised Crushing Unit (DCU) during 2009.
A total of 599.9 ton of sweet sorghum was harvested for kharif 2009 with an average stalk yield of 20 ton / hectare. The total quantity of juice extracted from crushing 599.9 ton of sweet sorghum was 1, 61,565 liters which yielded 28.8 ton of syrup. The average syrup production was 48 kg / ton of stalk and the total cost of production sweet sorghum syrup was Rs. 739, 528. Sweet sorghum stalk accounted for 57% of total cost of processing stalk to syrup followed by labour cost 29 per cent and 6 per cent for fuel. On an average, the cost incurred in processing 1 kg of syrup is Rs. 25.6. The returns realized from sale of syrup to ethanol industry was Rs. 356,000.

Comparison of yield & cost parameters of syrup production from DCU during 2008 and 2009.
Relative to kharif production of 2008, average stalk yield / ha increased by 34 per cent during 2009. Syrup production per ton of stalk during 2009 increased by 19 per cent in comparison to 2008. The cost per kg of syrup production declined from Rs. 31.4 per kg during 2008 to Rs. 25.6 per kg during 2009. The decline in cost of production is Rs. 6 / kg which 18 per cent decline from 2008.

Special Project Funding:
NAIP

<div align="right">P Parthasarathy Rao</div>

Output 9: Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations and policy recommendations developed and shared with partners.

Priority 5C, Specific goal 1: Identify mechanisms for the strengthening of producers organizations and for modes of participatory research

Priority 5C, Specific goal 2: Identify new forms of partnerships with NARS, the private sector, public extension agencies, NGOs and producers organizations, and public agencies from other sectors, such as environment and health to enhance the conduct and impact from agricultural research

Intermediate output target in 2009 : Development of hypotheses that will determine the IPG potential of ICRISAT's downstream work on technology development, testing and adaptation

Achievement of Output Target:
30%
This study will synthesize lessons learnt from past ICRISAT's downstream work and set the pace for embracing a culture of institutional learning and change. Review paper on the concept of IPGs in the CGIAR and the global agricultural research community, and analysis of earlier ICRISAT adoption studies, constraints analysis and impact assessments

Participating Countries:
The work plan covers three regional in-depth case studies (Asia, East and Southern Africa (ESA), and West and Central Africa (WCA)). The ICRISAT projects suggested include: a) development and deployment of the watershed-based approach in South Asia; b) seed supply systems in ESA; and c) fertilizer micro-dosing work in WCA.

Participating Partners:
Implementation of the case studies will be coordinated by GT-IMPI with the support of ICRISAT Research Committee (all GTLs, Directors of ESA and WCA and the DDG).

Objectives:
This initiative emerged from the EPMR recommendation #5, i.e. "The Panel recommends that GT-IMPI work on the development of hypotheses that determine the IPG potential of ICRISAT's downstream work on technology development, testing and adaptation."

With increasing focus on impacts and broader mandate of the CGIAR, and considering the weakening capacity of NARS in most developing countries, international agricultural research centers (IARCs) engage in research for development to address the range of issues facing the poor. Although development-oriented work is location specific, there is need to ensure that new knowledge is generated in line with the goal of producing IPGs that have wide applicability across countries. These IPGs may be developed by consciously developing indicators that assess how economic and social value can be extracted from knowledge and the processes by which this is achieved.

Methodology/Approach:
The approach will use process documentation, institutional histories and impact pathway analysis to identifying lessons and testable hypotheses that offer new insights to facilitate scaling up of technologies. This will be complemented by the analysis of research spillovers (relating internationality and IPGs) across the Asia and sub-Saharan regions. Technical information relating to the research processes will be elicited through wider dialogues among scientists across research themes and locations and with partners to reconcile impact-oriented downstream work with the delivery of IPGs.

Progress/Results & Policy Implications:
Analysis of discussions in various fora on the concept of IPGs indicates that balance between development-oriented research and IPG delivery is still a contentious issue. However, a thorough examination of studies undertaken in the past including adoption studies, constraints analysis and impact assessments reveals that lessons of IPG value can be learnt from downstream work. The first of a series of three in-depth reports is expected to be complete by early 2010, and the last one by September 2010. The synthesis of all studies will be analyzed and expected to be completed by Dec 2010 or early 2011.

Publications:
The strategic potential of applied research: Developing international public goods from development-oriented projects (working paper under review).

Special Project Funding:
EPMR Implementation Fund – Approved by DG

<div align="right">Kamanda Josey Ondieki and MCS Bantilan</div>

Intermediate output target in 2009: A thorough analysis of past and likely future research spillovers between Africa and Asia to guide ICRISAT resource allocations between those two regions.

Achievement of Output Target:
30%
ICRISAT commenced a thorough analysis of the past and likely spillovers by expanding its work on studying research spillovers to guide strategic planning and resource allocation across regions and programs with special focus on identifying common biophysical and socioeconomic conditions that enable the adaptation and sharing of innovations. Review paper on the concept of spillovers in the international agricultural research community, and analysis of earlier ICRISAT studies on research spillover benefits and experiences in inter-regional technology transfer, constraints analysis and impact assessments.

Participating Countries:
The work plan covers regions of ICRISAT (Asia, East and Southern Africa (ESA), and West and Central Africa (WCA)). The introductory background and review process of this study include following projects: a) breeding programs of ICRISAT mandate crops in Asia and Africa; b) participatory community watersheds in Asia and Africa; c) VASAT in Asia; d) technology transfer through institutional systems in Asia (CFC); e) fertilizer micro-dosing in Africa; f) integrated NRM - Sahelian Eco-Farm and African Market Garden in Africa; g) sustainable land management in Africa; h) nutrient management extension practices – mother-baby approach, farmer field schools, junior farmer field schools, organic matter (OM) management in Africa.

Participating Partners:
Implementation of the selected studies will be coordinated by GT-IMPI with the support of ICRISAT Research Committee (all GTLs, Breeders, Socio-economists, Principal Investigators of the respective projects, Directors of ESA and WCA and the DDG) NARS partners and stakeholders.

Objectives:
This initiative emerged from the EPMR recommendation #3, i.e. "the Panel recommends that a thorough analysis of past and likely future research spillovers between Africa and Asia to guide ICRISAT resource allocations between those two regions."

Panel was of the opinion that, a thorough analysis of the past and likely spillovers may be taken between Asia and SSA, starting with production statistics on an agro-ecological basis, which would help to inform priority setting for ICRISAT and it partners, and also help in allocating research resources between the two continents.

Methodology/Approach:
The approach will use a thorough literature will be reviewed to identify technologies for analysis, collect key parameters for estimating spillovers, conduct socio-economic surveys across regions, use GIS and crop models to determine impact target domains, estimate spillover benefits and finally synthesize key findings and draw lessons for the ICRISAT research prioritization and resource allocations.

Progress/Results & policy implications:
This study provides a broader assessment and synthesis of inter-state and international technology transfers derived from ICRISAT's research. It brings together the available body of evidence and knowledge on technology spillovers from the major research areas – crop improvement, Natural Resources Management (NRM) and socioeconomics and policy. It provides a list of varieties and other innovations developed in one region that have been adapted in other regions or countries. Despite its limitations, the assessment identifies several instances of technology spillovers within Africa and Asia as
well as a two-way transfer of germplasm and improved cultivars across the continents. With selected examples, the study tries to provide useful insights on the preferred characteristics of the technologies, the extent of spillovers, the enabling processes and constraints that limit wider adaptation.

Given the wider scope and interest of this study, the key milestones that would be achieved in this project include, a background review study expected to be complete by 2009, conducting socio-economic surveys across regions including use of GIS and crop models to determine impact target domains by 2010, estimation of spillover benefits through econometric framework by June 2011 and finally synthesizing key findings and drawing lessons by 2011.

Publications:
Spillovers benefits and experiences in inter-regional technology transfer of agricultural research: A review of studies (working paper under progress).

Special Project Funding:
EPMR Implementation Fund – Approved by DG

Person(s) responsible for this output target
Anand Babu Prakasham and MCS Bantilan

Intermediate output target in 2009: *Baseline survey reports related to crop-livestock linkages under the Fodder Innovation Project*

Achievement of Output Target:
60%
Socio-economic baseline surveys are an important component of monitoring and evaluation for timely feedback and learning and ultimately for assessing the impact of the project /intervention on the livelihoods of the project beneficiaries, and non-beneficiaries (via spill over effects).

Participating Countries:
India

Participating Partners:
ILRI, ICRISAT Foundation for Ecological Security (FES), RAGACOVAS, Watershed Organization Trust (WOTR)

Objectives:
For this study, the main objective of the benchmarking socioeconomic survey is to document the status of the livestock/fodder livelihood aspects in the identified pilot sites in India and Nigeria under the Fodder Innovation Project Phase II. The qualitative and quantitative benchmarks so established would help in identifying key indicators that can be monitored and measured during the course of the project and beyond.

Methodology/Approach:
The study was carried out at two levels, household and village level. Key Partner Organizations (KPOs) identified for each location would be the focal point for carrying out the surveys. The survey instruments (the village and household level questionnaire) were prepared by the Project and fine tuned by the KPOs through detailed discussions with farmers and key informants in the two villages. The data after entry into the spread sheets have been checked for consistency and analysed using SPSS version 10. The data are presented in frequency distributions, means and two-way cross-tabulations.

Progress/Results & Policy Implications:
The information collected from the surveys carried out in 2 villages each in Rajasthan, Maharashtra and Puduchery broadly pertained to the land and livestock holding , irrigation status, type of livestock owned and livestock production systems, availability and access to dry and green fodders and other feeds, seasonality of feed availability and management practices, institutional arrangements, problems and perceptions related to livestock and feed –fodder constraints and development.

The three locations provide three contrasting situations: Rajasthan where besides crop residues, grazing (and cut and carrying of hay) from own fallow lands were an important source of fodder. In view of the importance of fallow lands the interventions are to be implemented through grazing committees and similarly all natural resource management initiatives on land, water and vegetation have to be aligned with and built into the activities and control mechanisms of grazing committees. Generally the participation of respondents in community and institution related activities are high here.

Maharashtra: In both the project villages there is a severe shortage of fodder from April to June. This is also the period of lowest milk production. In terms of strategy in the village with higher irrigation interventions at the farm level in terms of improved dual purpose crops/fodder crops would be a solution. In case of the less irrigated village a strategy to increase fodder on select farms and its sale with in the village should be tried.

Puduchery: Due to rapid urbanization the land available for cultivation has declined. The land less who sell milk are the worst effected due to shortage of fodder. There is a need to bring the different actors in the fodder –milk chain on a common platform so they can develop trust and promote milk production by small scale and land less farmers

Special Project Funding:
DFID through the System-wide Livestock Program in ILRI

<div align="right">P Parthasarathy Rao and MCS Bantilan</div>

Output target 2011 1.9.1 Policy report on impact of rainfall insurance and recapitalization of cooperatives in India

Comments:
The follow-up survey of rainfall insurance which was initiated with baseline surveys in 2004 is completed with 2160 respondents from 72 villages drawn from six districts of Andhra Pradesh and Orissa. The second follow up survey of rainfall insurance which was expected to be completed during 2009-10 is discontinued due to renegation of funds by the World Bank.

<div align="right">KPC Rao</div>

Output 10: Livelihood, institutional and policy options for investment and risk management for SAT poor developed and promoted with associated capacity building for partners

Output target 2009 1.10.1 Database and documentation of 'Changes in household economies on SAT Asia' based on the panel data from 1975-2007 completed; VLS webpage developed

Intermediate output target in 2009

Achievement of Output Target:
75%
To produce exceptionally high quality data from continuous engagement of resident field investigators and double entry book-keeping system and make the data available on the internet free for the use of researchers worldwide

Participating Countries:
India, Bangladesh (India's SAT, India's Humid Tropics, and Bangladesh's Humid Tropics)

Participating Partners:
IRRI, NCAP and CPD

Methodology/Approach:
The CS-PRO software is being used and the double book-keeping system of data entry is continuing as in the past

Progress/Results
The on-going activities include database development and management, periodical and synthesis reporting, website development and management and software development for data processing and dissemination.

A documentation for second generation Village-Level Studies (VLS) was completed in two parts in 2009. This documentation includes the objectives and purpose of first generation VLS (1975-1984) as well as the additional features of the second generation VLS starting 2000-2001. The documentation extensively describes each module under VLS for which data is collected as well as the coding and enumeration method. The documentation is under review for final release.

Similar kinds of efforts are in progress for the VDS project starting 2009. Software development is also underway for summary files via final editing programs for distribution in standardized econometric software packages such as SAS, STATA and SPSS.

The SAT India dataset for 2001-2008 is entered, proof read and validated and ready for uploading to the web. The process of development of project webpage is on going and it may take another 4 months to complete. The databases along with documentations and sample schedules will be uploaded once the webpage is ready. The electronic data sets on the webpage will not only include the raw data but will also contain estimates of summary variables, such as household income.

Special Project Funding:
Bill and Melinda Gates Foundation

Person(s) responsible for this output target
MCS Bantilan, VR Kiresur, P Parthasarathy Rao

Output target 2009 1.10.2 Report on rural livelihoods in West-Africa completed

Achievement of Output Target:
This activity was completed at 75%.
Report summarizing VLS data 2004-2006 and launching the project "Assessing the Dynamics of Poverty" and develop survey instruments to be implemented

Participating Countries:
Data were collected from 3 agro-ecological zones, mainly 2 villages in the Sahelian zone, 2 villages in the Sudano-Sahelian and 2 villages in the Sudanian zone

Participating Partners:
NARS partners from the participating countries

Objectives:
The major objectives were to:
- Improve understanding of technology uptake processes and assess uptake pathways and their impacts on poverty, food security and livelihood strategies.
- Identify and assess household investment strategies and development pathways pursued by households.
- Formulate recommendations and develop implementation guidelines for policy, development, institutional and research interventions to facilitate adoption of innovations.

Progress/Results:
The data set for 2004/05, 2005/06 and 2006/07 have been entirely analyzed by module. This has been presented during the EC review in November 2009 in Bamako, Mali. Descriptive statistics have been computed on the modules including census of households and cultivated crops, land assets, household migration, household equipment, input-output production data at plot level, plot characteristics, household transactions, crop production stocks and flows, livestock stocks and flows, labor use, credit transactions, income diversification, institutional affiliation, wealth indicators, major risks facing households, and major diseases that have occurred during the last 5 years from the date of the survey.

The data set in 2004 included 252 households of which 86 households during the 1982-85 data collected. In 2005/06; 270 households of which 59 households during the 1982-85 data and finally, 266 households oh which 99 households collected from the 1982-85 data set. Data were collected from 3 agro-ecological zones, mainly 2 villages in the Sahelian zone, 2 villages in the Sudano-Sahelian and 2 villages in the Sudanian zone. The villages Samari and Sadeizi Koira are located in the zarmaganda, a deficit crop production region north of Niamey with long-term rainfall averaging 400 mm, limited agricultural potential, a severely deteriorated resource base with difficult road and poor market access. Two other villages (Goberi and Fabidji) are located in the Dallol Bosso, an intermediate crop area southeast of Niamey with long-term annual rainfall averaging 600 mm with potential for irrigation in the Dallol; easily accessible by road with access to large markets. Finally, 2 villages Faska and Hankoura were selected from the Sudanian zone with 800 mm on average.

Survey results indicate that villages located in environments easily accessible by road in the higher rainfall zone have experienced large economic transformation with significant improvement in households' income and well-being. Farmers located in villages with low rainfall zone who are reporting their inability to secure food for their families. Livestock, migration and long distance petty trade in Niamey are the main source of cash income. Agriculture contribution to rural livelihood is more and more limited.

1. Households have accumulated more assets and are using more modern technologies in the high rainfall zone of Fabidji and Gobery than in the low rainfall zone of Sadeizi Koira and Samari.
Household livelihood assets have increased in better rainfall areas. In effect, the proportion of households owning carts has increased by twofold in Fabidji and Gobery and remain stable in Sadeizi Koira and Samari. Ownership of draft animals has also significantly increased. The proportion of households using inorganic fertilizers has increased significantly in the more favorable rainfall zones of Gobery and Fabidji. In all villages many more households are using organic fertilizers than was used in 1982-87. There are signs of agricultural intensification in some villages as a result of increasing land scarcity.

2. Households are diversifying more within and outside the agricultural sector especially in more favorable rainfall areas.
In Gobery and Fabidji, the presence of the Dallol (with assured water) has provided opportunities for farmers to diversify within the agricultural sector especially into high value crops such as vegetable and fruit production. Farmers have also diversified into the secondary and tertiary sectors mainly due to market opportunities. In low rainfall areas of Samari and Sadeizi Koira, there are few opportunities to diversify within the agricultural sector due to poor climatic conditions. Farmers also have few opportunities to diversify outside the agricultural sector. Long distance trading of wood, cowpea haulms or millet stalks and migration are the main activities. In all villages, non-farm income represents a larger share of household income in 2004-06 than in 1982-87.

Overall, access to infrastructure especially roads and markets opens more opportunities for income diversification within and outside the agricultural sector. Policy, institutions and technological changes likely to bring about some agricultural transformation are those that would improve the access to infrastructure including roads and markets.

3. Livestock has increased in less favorable agricultural areas compared to more favorable rainfall zones
Livestock rearing is practiced in all the 4 villages surveyed. During the last 25 years, population density and subsequent reductions of grazing areas are forcing households to move into semi-intensive modes of livestock rearing. Both men and women practice livestock fattening. Crop-livestock interactions are stronger in the low rainfall zone than in the high rainfall area. There is a need to develop crop and production technologies that will increase the supply of feed resources, and to identify and develop institutions and policies that will enhance the development of the livestock sector.

4. The use of modern varieties has remained very limited.
Despite numerous efforts at disseminating modern sorghum and pearl millet varieties in the 4 villages, farmers are still using their local varieties. Only limited yield gains have been obtained from the adoption of most new varieties, because these varieties have not been linked with the adoption of improved management practices.

In the past, crop improvement has been based largely on conventional breeding methods. These have been highly successful but a number of biotic and abiotic stresses continue to limit yields. There are now calls for more investment in biotechnology to work on beneficial crop traits that conventional breeding has found intractable. But biotechnology will only work for the poor if it focuses on traits that are important to resource poor farmers or consumers.

One strategy for increasing research impacts was to promote more participatory methods of technology development. This undoubtedly improves the likelihood of adoption if the seed is ultimately made available. Research and development priorities should consider targeting technologies to different types of households and environments. Rural poor who live in environments with poor agricultural potential, underdeveloped markets and infrastructure are likely to be targeted for food security attainment purposes, whereas in areas with better farming conditions and market access, research programs should focus market oriented production and value addition. Overall, there is a need to better understand and identify the changes in the biophysical and socio-economic environment and how they impact on poverty, food security, and the natural resource base.

In high rainfall areas, there may be more potential to promote pearl millet based technologies provided farmers diversify and derive more income and cash to be able to purchase inputs. Technologies such as the African market garden pursued by ICRISAT are viable options to pursued provided farmers have access to credit. Policies and programs that could help address the credit constraints will facilitate uptake of technologies.

In the low rainfall areas, a combined effort in developing crop production technologies that will increase the supply of feed resources, and to identify and develop institutions and policies that will enhance the development of the livestock sector is necessary. The use of biotechnology tools to address the drought stress issues in germplasm is highly desirable.

 Data collected were based on one time survey and may not have the same level of confidence as if the cost accounting method was used. On this basis, a project entitled "Assessing the dynamics of poverty in the Sahel" was funded by IDRC and was launched in July 2009 was funded.

A PRA of the 4 ICRISAT villages in Niger was undertaken 2009 to assess the changes in livelihood outcomes and strategies that have occurred during the last 30 years and identify a range of hypotheses to be tested in this project. This activity is essential for ICRISAT strategic planning. Eight villages were selected including 4VLS villages. A set of survey modules were developed using a cost accounting procedure to collect data.

Special Project Funding:
Data not available

<div align="right">Jupiter Ndjeunga</div>

Output target 2010 1.10.2a Case studies on livestock and livelihoods in Zimbabwe published

Intermediate output target in 2009

Achievement of Output Target:
 90%

Rationale:
Crop–livestock systems are the most important livelihood activities for small-scale farmers in semi-arid Zimbabwe. These areas have been severely affected by drought spells from 2001 to 2006, as well as a sharp decline in economic growth. The impacts of drought have been exacerbated by unemployment, hyperinflation, and a dramatic drop in GDP since 2000. The economic decline has also resulted in shortages of basic agricultural inputs and services, and a collapse of market and trade operations. At the time of data collection, market operations were further restricted by limited market licenses, price slashes, and cash shortages.
In spite of this difficult situation, opportunities for small-scale farmers exist in the crop–livestock sector. These low input systems are currently not very productive, but provide food security and most of a households' on-farm income. Cattle are mainly kept for draft power and milk. Goats are sold to purchase food items and fund educational expenses besides contributing directly to the food supply through the provision of meat and milk. The growing demand for livestock products in the region can provide the necessary incentive for farmers to invest more in livestock production and marketing.

Participating Countries:
Mozambique, Namibia, Zimbabwe

Participating Partners:
ILRI, Mozambique and Mozambique Agricultural Research Institute (IIAM), in Namibia Namibian National Farmers Union (NNFU), in Zimbabwe Department of Agricultural Research for Development/Matopos Research Station., Organisation for Rural Associations for Progress (ORAP), The Netherlands Development Organization (SNV), Department for Livestock production and Development (DLPD), Department of Agricultural Research for Development/Matopos Research Station

Objectives:
The study objectives are to characterize challenges and opportunities relating to the commercialization of goat and cattle production by small-scale farmers and serve as a base for decision making and associated dialogue among key stakeholders.

Methodology:
The case studies present and analyze the study results on goat production systems in Gwanda and on cattle production systems in Tsholotsho. The data collection combines results from baseline surveys (household surveys and PRAs) with multi-stakeholder discussions at Innovation Platforms (IPs). The studies evaluate the implications of livestock production and market development for areas with different market potential and different wealth groups and gender. For the household survey (livelihood assets, food consumption, livestock marketing and management), at each study site about 45 households were randomly selected in three villages. The PRAs (livelihood analysis, resources mapping, time line and actor analysis) were conducted in the same villages.

Progress/Results:

The study report highlights the relation between poverty, livestock, markets and technology development. Poverty is a critical challenge at the project sites. De jure female-headed households are poorer with smaller herd sizes, smaller land holdings and limited off-farm incomes, whereas de facto female-headed households were better off in terms of access to cash. More than a quarter of the households did not harvest any crops in the previous 2006/07 season and many farmers did not consume any self-produced cereals during the 30 days prior to the survey which was at the end of the dry season when the reserves tend to be depleted. During these critical times, most farmers purchased cereals, often financing this by selling animals, or they received cereals as remittances.

Livestock is the most important source of cash income. Since the observations were made at a time of exceptionally difficult social and economic conditions, this situation also illustrates the value of livestock during times of external shocks. Most farmers rely on crop production to ensure food security, but as most harvests failed in the previous season, farmers were compelled to sell animals to purchase staple food. However, the markets for livestock are not adequately developed and prices were therefore low.

The nexus between a household's livestock herd sizes, off-take and the need to sell to address household cash requirements is a critical dynamic. Poorer households sell a greater proportion of their smaller herds to make ends meet, whereas wealthier households sell more animals, but this constitutes a small proportion of their herds. Poorer households are thus unable to increase herd sizes in the light of observed mortality rates and cash requirements.

The main production constraint is the unacceptably high mortality rates observed in all the study areas. The total outflows from herd losses through mortality were about 20% − more than double the total productive outflows of goats in Gwanda and almost tenfold the outflow of cattle in Tsholotsho. Therefore, the first step to increase production and productivity would be to reduce mortality. Significant impact can be achieved through the reduction of mortality of both goats and cattle. Since mortality is primarily a function of animal husbandry, disease and dry season nutrition, entry points should focus on improved animal health and nutrition.

The potential of livestock markets but not market distances turned out to be the critical factor. The higher market potential sites for livestock marketing were far from regional towns in both areas. Settlement and cropland expansion was less, preserving rangelands at better quality and herd sizes were larger. In areas close to towns there was more emphasis on crop production and alternative sources of income and remittances.

In Gwanda there is a potential to enhance commercial goat production. Farmers had a higher inclination to sell goats in the area with better-developed goat markets. In this area more than 50% of the farmers participated in goat sales and sold on average 12% of their herds annually. A substantial number of farmers also sold at sale pens (25.9%) and to traders (48.1%). Here, 50% of farmers owned herds in excess of 20 animals. Farmers also had established livestock clubs to promote their economic activities. The formal administration was more engaged in maintaining market infrastructure and supported market organization, and more traders attended the markets. These actors could play an important role in facilitating higher offtakes, whereas in the area with poorly developed markets, farmers depended on farmer-to-farmer sales and had a limited potential to participate in markets with goat herds averaging less than 20 animals. Farmers and other market players thus reacted positively to market development where sufficient goats were available. This is a very strong argument that market development could encourage farmers to increase off-take rates and increase investments in production.

The potential to commercialize cattle production is limited in Tsholotsho. Although formal markets for cattle were established, farmers' participation in markets was generally low and mainly at the farm gate. Traders also seem to buy most cattle at these informal markets. The differences between the two sites in Tsholotsho in relation to market potential were also not very pronounced. An explanation might be that farmers hold on to their cattle, since they need to ensure sufficient draft power for their cropping activities. The underdeveloped markets for livestock do not really offer incentives for farmers to invest in management options. Even if farmers know about the technologies they are reluctant to invest, as they do not realize the returns on their investments. Beyond cropping there is however a ready market for meat and cattle are the most important on-farm source of larger amounts of cash income. Farmers can make substantial income from cattle sales.

The baseline surveys identified the most critical challenges. These include:

- Market institutions: Functional market institutions were absent. The traditional authorities were very important in passing on information regarding market events. The Rural District Councils (RDCs) were responsible for maintaining market facilities and organizing the sales. It was however beyond their capacity to control the livestock market operations, grading and price setting, and to ensure the supply of inputs such as vaccines, feeds and water. Furthermore, farmers did not understand the purpose of collecting levies and the reinvestment of levies was not transparent to them. Lack of collaboration between farmers, market players and input and service providers rendered the coordination of market operations inefficient.
- Inputs and support services: Limited access to inputs and services, lack of knowledge and affordability seemed the main constraints to improved feeding and animal health. While government support services are often poor or lacking, the private sector has a major role to play and facilitating public private partnerships is critical to facilitate livestock development.
- Production technologies: Farmers were aware of feed shortages and there is limited but growing investment in improved dry season feeding. Many farmers started collecting and feeding crop residues; however, without proper harvesting and treatment their nutritional value was not sufficient to enhance livestock productivity. Low crop yields implied that few crop residues could be used for feeding livestock. Planting forages and technologies for processing and storage were developed but most farmers did not know how to use them. Making use of available residues from irrigation schemes was not exploited. Feedlots had been constructed but were not operational. Commercial stock feeds were not available as the suppliers have closed their outlets. Feed markets using and processing locally available feed material have not yet developed. Income opportunities for farmers without livestock to produce feed and fodder were not yet exploited.
- Communication: Farmer-to-farmer information flows were the most important means of communication, whereas linkages to outsiders and thus access to new information were missing. Lack of effective means of communication made the organization of market events difficult. Farmers faced difficult access to specific market information and prices. It was also difficult for farmers to demand inputs and services from government and policy makers.
- Financial assistance: Financial assistance is commonly given to support food security and this is related to crop production. The role of livestock is not reflected in the budgetary provisions, policy and other public sector support frameworks. Access to private sector support (loans) also does not exist. Without such financial support it will be difficult for farmers to obtain adequate dry season feed and animal health inputs on an economically sustainable basis.

Any Comments/Explanations:
These results contributed to test urea treatment of crop residues, combined with animal health interventions (vaccinations and dosing), at the pilot sites. A Farmer Field School approach was applied to promote these technologies and enhance joint learning among farmers and encourage an alternative extension system. More details are in the AET reports.
A publication on The potential for engaging women in improved livestock water productivity: a case study from a crop-livestock system in Nkayi district, southern Zimbabwe by Senda et al. provides further details on gender implications. More details are in the AET reports.

Special Project Funding:
- LILI: Markets: In Mozambique ILRI and Mozambique Agricultural Research Institute (IIAM), in Namibia Namibian National Farmers Union (NNFU), in Zimbabwe Department of Agricultural Research for Development/Matopos Research Station.
- EU/ORAP: Organisation for Rural Associations for Progress (ORAP), The Netherlands Development Organization (SNV), Department for Livestock production and Development (DLPD), Department of Agricultural Research for Development/Matopos Research Station

Sabine Homann Kee-Tui

Output target 2010 1.10.2 Uptake pathways of SAT technologies documented based on case studies and shared with national program partners in Asia

Intermediate output target 2009: Does an Improved Crop Cultivar Impact on Land Values?

Achievement of Output Target:
100%
The report is completed and submitted to London School of Economics and Political Science as a requirement for the Masters degree

Participating Countries:
India

Participating Partners:
London School of Economics and Political Science   : Hyunjoo Yang
ICRISAT   : P Parthasarathy Rao, MCS Bantilan

Progress/Results:
Despite the importance of land in socioeconomic aspect of rural societies, research on how farmers actually determine the value of land and what kind of external factor influences the perception is hard to find. The motivation of this paper is to look for the link between technology adoption, one of possible external factors, and land value. Specifically, this paper tests the hypothesis that an adoption of new improved variety impacts on the perceived land value. Since a controlled experiment of a crop adoption by farmers is seldom feasible, the main hurdle of the empirical analysis is to tease out the impact of the adoption from other factors that influence land value.

In a non-experimental study, the preferred situation would be that we have one group that adopts a new variety and another similar group who does not due to some exogenous reason. Then the comparison between two groups would reveal the land value appreciation associated with the adoption assuming the econometric model is correct. However, when most farmers in a village adopt the variety, a different approach for the analysis is needed. The relationship between adoption and land value is attempted by identifying and comparing groups with different degree of risk aversion in crop adoption, and systematic difference in perception of land value among the groups. Cropping pattern was used as a proxy for the degree of risk aversion. Risk loving farmers fully adopt the new crop in the initial year when the seeds were available, while other groups adopt partially. The group, which is more willing to adopt the new improved crop, expect higher profitability from the land. Hence, the group would value the land higher than other groups after the initial year of adoption.

However analysis shows that there is a statistically significant difference in the land value between a group with full adoption and another group with partial adoption after controlling for other factors. There is no evidence of any difference among groups in the trend of land value before the adoption. The analysis is based on the historical event of the adoption of Castor Aruna, a high yield variety, in Aurepalle Village in early 80's. Aurepalle was one of six study villages of ICRISAT's Village Level Studies project in semi-arid tropics in India.

The theoretical framework of the analysis is two fold: 1) Evaluation of the determinants of land values based on Ricardian Rent Theory; and 2) Development of a simple model that explains the different degree of risk aversion of adopting a new crop leads to varying level of land value.

Followed by the framework, an econometric model based on opinions of land valuation gained from farmers who were the respondents of the VLS data. Since the perceived land values are recorded by the farmers themselves, this ensures the specification to capture important factors influencing land values. Least squares dummy variable method was used for the estimation. The method exploits panel structure of data to control for important unobserved time-constant factors, such as road access.

Based on empirical evidence, it is found that an adoption of new improved crop cultivar impacts on perceived values of land. For this study of an improved variety of castor, the estimates show that the trend of land values significantly differ among groups of farmers with varying degree of the risk aversion of adopting a new variety. The group, who is relatively more willing to adopt the new crop, values their land more. This evidence has implication for impact assessment that the benefits of adopting new varieties could be underestimated since the assessment does not account for the appreciation of value of their most important asset.

Special Project Funding:
Nil

Hyunjoo Yang, P Parthasarathy Rao and MCS Bantilan

Intermediate output target 2009: Self Help Groups and Microfinancing: Insights from Aurepalle Village, Andhra Pradesh

Achievement of Output Target:
100%
The report is completed and submitted to University of London as a requirement for the Bachelor's degree

Participating Countries:
India

Participating Partners:
University of London   : Pathumi Ruchika Abeysekera
ICRISAT   :, R Padmaja, MCS Bantilan

Objectives:
The main objective of this analysis is to ascertain the functioning of the micro finance activities in the Aurepalle village.

More specifically, the investigation seeks to:

- Examine the Organizational, institutional, procedural and operational aspects of SHGs with a view to understand their effectiveness as tool for developing the economic and social well being of the poor women in Aurepalle village.
- Understand the operational and functional features of micro finance activities adopted by the SHG members in the village and also to examine the roles and responsibilities of the SHG members in carrying out micro finance activities in their village.
- Assess to what extent the strategy of introducing SHGs and Microfinance programme in to Aurepalle village have contributed to uplift the livelihood activities and to improves the economic well being of the SHG members.
- Identify the overall results emerging from implementing the SHGs and the micro finance programme in the village, key constraints/issues, and suggested solutions.

Progress/Results:
The study is basically designed to understand how the SHGs and micro finance activities are functioning in the village of Aurepalle and to see to what extent the SHGs and microfinance systems are helping the village population to improve their livelihood and to empower them. Aurepalle village is remote village, located in Mahabubnagar in Andhra Pradesh. It is one of the six villages included in the Village Level Studies (VLS) programme of ICRISAT and monitored over the past 30 years. The data gathered through the VLS suggests that in terms of women empowerment, Aurepalle village have a pioneering role.

Results of this investigation reflect that the microfinance through SHGs in Aurepalle has laid a firm foundation to change the village socio-economic system. The investigation indicated that previously the women in Aurepalle village were relegated to the background with little ability to raise their voice because of a mix of factors including their lack of education, conventional social barriers, no availability of employment, very low levels of incomes and inaccessibility to financial resources. The results of this study indicate that the SHGs have provided them with an effective institutional mechanism for unification of women on a common platform. Information gathered in this study showed that the SHGs have enabled the members in the SHGs to inculcate the savings habit which in turn has enabled to borrow from institutional finance at low interest rates, acquire information and knowledge on a number of village related activities, adopt income generating livelihoods and to achieve higher levels of incomes and better family welfare. The microfinance led group process has allowed the women members to take their own, informed decisions on issues affecting their own destiny. This in turn has provided substantial change at the household level as well as at the community level in Aurepalle village.

The study findings suggest several areas that may be adopted in Aurepalle for achieving better results. Such improvements include areas such as training the group members and office bearers on their roles and responsibilities, keeping accounts and maintain transparency and financial viability in their accounting systems in, building linkages between village level income generating activities to commercial activities outside the villages, exposure to good practices.

Special Project Funding:
Nil

Pathumi Ruchika Abeysekhara, R Padmaja and MCS Bantilan

Output target 2011 1.10.4 Policy package elements on risk management strategies for mitigating the impact of risks inherent in rainfed agriculture developed and shared with partners in Asia
Intermediate output target in 2009: Data collection, coding, validation and preliminary analysis of the data to map the network architecture of rural villages

Achievement of Output Target:
70%
Parallel to the information revolution (which has given birth to new economies structured around flows of information and knowledge), social networks have also grown stronger as forms of organization of human activity. Social networks are nodes of individuals, groups, organizations, and related systems that tie in one or more types of interdependencies: these include shared resources, values, visions, and ideas; social contacts; kinship; conflict; financial exchanges; trade; joint membership in organizations; and group participation in events, among numerous other aspects of human relationships. When they succeed, social networks influence larger social processes by accessing human, social, natural, physical, and financial capital, as well as the information and knowledge content of these. Put simply in development work, they can impact policies, strategies, programs, and projects— including their design, implementation, and results—and the partnerships that often underpin these. To date, however, we are still far from being able to understand and design ways that can harness their potential. Understanding when, why, and how social networks function best is important. It is here that social network analysis plays an important role. Social network analysis (SNA), sometimes also referred to as 'structural analysis', is a broad strategy for investigating social structures. The traditional individualistic social theory and data analysis considers individual actors making choices without taking the behaviour of others into consideration. This individualistic approach ignores the social and economic context of the actor. In SNA, however, the relationships between actors become the first priority, and individual properties are only secondary.
Participating Countries:
India

Participating Partners:
Indian Institute of Technology, Bombay   : Profs D Parthasarathy, Sarmistah Pattanaik and KN Narayanan
ICRISAT   : R Padmaja and MCS Bantilan

Objectives:
Though there is plenty of literature on social networks and their role in influencing decisions, more methodological and conceptual work is needed to understand the network conditions that best help to nurture and support the many aspects of rural communities. The focus of this study is on the Semi-Arid Tropics (SAT) poor engaged in agriculture, the marginalized groups especially women.

Methodology:
Typically, social network analysis relies on questionnaires and interviews to gather information about the relationships within a defined group. The responses gathered are then mapped. This data gathering and analysis process provides baseline information against which one can then prioritize and plan interventions to improve knowledge flows, which may entail in some cases, recasting social connections.

Methodological and design aspects of the study include participatory and inter-disciplinary research involving qualitative and quantitative methods, social network analysis, gender-based social analysis using qualitative tools. This will include mapping of the network architecture (including networks developed either through formal organizations, kinship groups, neighborhoods networks, work groups, self-help groups, or informal interactions) for investigating the flow of information, access to new opportunities and identifying the hubs or focal points for introducing interventions . The analysis of these network maps will also address how and why are social networks fragmented within communities? Which collective benefits could emerge from creation of new links?

The methodology for understanding village dynamics and social relationships and networks was developed in 2008. In the past twenty years many sociologists have worked to expand network concepts into a structural formulation. Greatly increasing the scope of and claims of network analysis, they seek to treat all social structures as social networks. The diversity of contemporary research is a result of sociologists linking network concepts with a variety of technical and substantive concerns. These include the works of : Simmel (1971) with an emphasis on the pattern of ties affecting social behavior, Freeman (1979), who used a sociometrically based desire to measure network properties quantitatively; an epidemiological and communications interest in resource diffusion process (Coleman, Katz and Menzel, 1966; Rogers 1979); and a contemporary bent in mathematical reasoning (White 1965; Lorrain and White 1971).

Some perspectives on how to sample social networks was presented The 2008 Archival Report . As discussed in that report, it can be summed up that steeped in quantitative traditions, many sociologists have sought to describe the structure of network as precisely as possible. While some researches analyze whole networks – all the ties of a certain kind among all the members of a population – to study the underlying structural patterns of links between large groups such as corporations (Levine, 1972; Berkowitz, 1982), others analyze personal networks – to study how the composition, content and configuration of ties affect the flow of resources to focal individuals (Gottlieb, 1981; Wellman, 1981a). By and large, many scholars have been concerned with the effects of network properties on the integration of large-scale social systems. Based on the review and expert consultations with Drs Hans Binswanger and Mark Rosenzweig, I undertook a complete census of the two study villages to capture village dynamics and social relationships both within and outside the villages. A survey instrument was developed to collect information on the major transactions – economic, socio-cultural-political and technology related – from all adult members in the village. The questionnaire documents all the major transactions each individual member in the household has had during the year 2007-2008.

SNA will be carried out for mapping the different layers of networks. UCINET software will be used to do this analysis. This analysis will be complemented by some simple statistical analysis of the data, key informant interviews and some qualitative tools. Essentially, through a network analysis the patterns of relations between actors will be mapped.

A detailed registry of all individuals in the village and their immediate family and business associates is documented through the enhanced village censuses which captures key transactions and relationships within and outside the village. This will allow for innovative quantitative and qualitative analysis of social networks to capture socioeconomic-cultural-political village dynamics through network mapping using detailed village registries.

The total sample size in the study villages is as 3735 respondents and the number of observations for which data is collected is approximately 20628 in Aurepalle and 15000 in Kanzara. This is based on the number of transactions each individual in the village has with another individual, group or an organization. On an average, each adult member in the village has the eight major transactions per year.

Progress/Results:
Coding and validation of the data for Aurepalle is completed. This is one of the most tedious and time consuming exercise which was experienced. This was done in two parts. First, each individual member in the village is assigned a unique id . The next step was to assign the same unique id in the transactions module/tab in which all the transactions of all the village members was entered. This exercise took a very long time as it involved validation of the data also at the same time the unique id codes were being assigned. Similar coding is done for the transactions within the village as well as outside the village. This method of coding and assigning unique ids was undertaken after serious and careful discussions with my research supervisors, and expert consultations with Drs Hans Binswanger and Victoria Reyes. Similar method of coding is underway for the Kanzara village data set.

Understanding formal and informal networks and their contribution to the construction of social capital is necessary to perceive how men and women farmers increase their individual status, mobilize and acquire a wide range of assets, and manage the decision making processes regarding adoption of technologies, access to resources and to markets.

This research will establish the network architecture of men and women in rural communities in two villages in India and thereby measure social connectedness by mapping farmer networks within villages and outside villages. This will help in particular to identify local networks already in place that will facilitate layering new innovations and intervention; and groups or households that are not socially connected, and thinking about how their needs can be included. The findings may assist in designing strategies, policy formulation and institutional arrangements for technology intervention.

Understanding the network architecture of the farming communities will also assist in identifying the route and the channels through which the uptake and diffusion of technology is fast and also maximum. The adoption of new technology is a central feature of the transformation of farming systems during the process of economic development. If there are many farmers in somewhat similar circumstances, then the process of learning about the new technology may be social. Farmers may learn about the characteristics of the new technology from their neighbors and through the interactions they have with other members in the community based on the relationship they share with them. A

number of recent papers, examine how individuals in developing countries take into account the experiences of their social contacts when deciding whether to adopt new technologies, generating a process of social learning. Such social learning could provide a rationale for public policies, such as agricultural extension, that subsidize early technology adoption. Benefits to the community includes increased incomes through enhanced linkages, greater access to resources through altered property rights regimes, and new governance mechanisms based on participation and inclusion of community members.

The new data collected will offer a unique, gendered data set on social networks, linked to a unique 30-year household and individual panel data set. These data can be used to establish the ex-ante determinants of men and women's differential and changing choices of participation in collective action.

Any Comments/Explanations:
It is proposed to complete the following activities in 2010
1. Analysis of the enhanced census data:
   • analyze the types of social networks that men and women farmers associate with (network architecture of men and women)
   • the networks that powerful groups have access to (network maps of key focal points/nodes),
   • mapping the network architecture developed either through formal organizations, kinship groups, neighborhoods networks, work groups, self-help groups, or informal interactions
   • Network maps based on the transactions – economic, social and technological
   • Network architecture by households overlaid by network architecture of the individuals

This will provide answers to questions such as:
   • Who interacts with whom? And in what way
   • How do networks operate?
   • What is the outcome?
   • How do networks affect outcomes?
   • Are the well connected well off?

2. In addition to the village censuses to capture relationships and networks, it is proposed to undertake data collection with a focus on technology adoption and adaptation. This will be in Kanzara in Maharashtra where I will attempt to understand the role of social networks in the uptake or adoption of Maruti and hybrid pigeonpea seed technology. The sampling process will follow the egocentric with alters approach (based on the network map that emerges from the analysis using the enhanced census data) and will also include the original 40 households currently being studied as part of the ICRISAT Village Level Studies in addition. It will also include adopters as well as non-adopters of the technology. Through this survey information will be collected on
   a. context/circumstances when the technology in study was introduced
   b. motivations for the people to adopt the technology
   c. actual technology uptake
   d. how do networks facilitate technology uptake and adoption

3. Some additional qualitative surveys /case studies using qualitative tools will be carried out to get in-depth sociological perspectives on
   a. Networks of SHG group members Vs non-members
   b. Networks of those who have local links/connections Vs those who have global links
   c. Tracking Maruti pigeonpea adoption - kinship network

An after thought from the above is - What are the research questions and hypothesis which can be confirmed, which can be done only through social analysis using qualitative tools

Special Project Funding:
DG's Special Fund

<div align="right">Padmaja R and MCS Bantilan</div>

Output target 2012. 1.10.0 Project proposal entitled, "Tracking change in rural poverty in household and village economies in South Asia" operational – funding received from BMGF

Based on the various activities detailed in the Archival Report 2008, , a full project proposal entitled, "Tracking Change in Rural Poverty in Household and Village Economies in South Asia" was developed and submitted to the Foundation for their review and approval.   This was approved in early 2009 but the project was functional since May 2009. The charitable purpose which is envisioned through this project is to decrease the incidence and severity of absolute poverty in South Asia's semi-arid and humid tropics by markedly increasing the availability of time-series district-, household-, individual-, and field-level data.

This project seeks to improve the quantity and quality of time-series meso- and micro-data so that decision-making is based on evidence on impacts on the poor. The project is driven by three initiatives: the compilation of longitudinal household, individual, and field data over five years in 42 villages, the assembly of secondary meso-level agricultural data into integrated data bases for distribution, and the nurturing of policy and data analysis, and capacity building.

This project is guided by over 30 years of previous work that establishes a basis for structuring partnerships to enhance sustainability, for assessing risk, and for innovating over time. That experience shows that a large share of the benefits from the proposed work will accrue to society years after its projected completion. Tracking poverty should be interpreted broadly as the proposal's foci on why and how changes in natural hazards, government programs, market prices, and institutions are mediated in village and district settings and affect the poor over time.
The project is operational since May 2009.

<div align="right">MCS Bantilan, P Parthasarathy Rao, VR Kiresur,
R Padmaja and GV Anupama</div>

Output target 2012. 1.10.1 Gathering longitudinal data on households, individuals and fields in 42 selected villages in years 1-5 of the project

***Intermediate output target in 2009:* Village Reconnaissance Visits and Focus Group Meetings**

Achievement of Output Target:
100%

Participating Countries:
SAT India

Participating Partners:
ICRISAT, NARS Partners [UAS Dharwad, JAU Junagadh, JNKVV Jabalpur

Objectives:
As proposed in the project proposal funded by BMGF, 18 villages were selected from 5 states in SAT India, namely, Andhra Pradesh, Maharashtra, Karnataka, Gujarat and Madhya Pradesh at the rate of four villages in each of these states except Madhya Pradesh wherein it was two villages. To start with, the SAT districts in all these five states were segregated and from these districts, two districts each in Andhra Pradesh, Maharashtra, Karnataka and Gujarat and one district in Madhya Pradesh were chosen based on certain criteria, namely, rainfall, poverty, proportionate area irrigated, soil types, cropping pattern and infrastructure index. Further, from each district, one or two talukas/tehsils/ mandals were chosen mainly based on two criteria, namely, poverty and rainfall. Lastly, two villages were chosen from each district based on several criteria, namely, cropping pattern, proportionate irrigated area, caste composition of population and soil types.

Methodology:
To select these 18 villages in SAT India, reconnaissance visits to 48 villages spread across five states in SAT India were organized. And 48 focus group meetings at the rate of one per village were conducted during these village reconnaissance visits.

Progress/Results:
The important observations during the reconnaissance visits are as follows
These visits were highly educative in terms of providing an opportunity to understand the ground realities in village/rural dynamics.
- Even within the Semi-Arid Tropics, there is lot of diversity amongst the villages visited in terms of rainfall, soil types, cropping pattern, land tenure, distribution and size of land holdings, irrigation sources and capacity, institutional arrangements, social set up, culture, linguistics, etc.
- The population of each village ranges from 1000 to 8500; the household number ranges from 210 to 1000; agricultural land varies from 300-15000 acres; irrigated area ranges from 10-100%; number of bore wells from 5-2000 and open wells from 20-1000; depth of bore wells from 300-500 ft.
- In general, Gram Panchayat, anganwadi, primary school, credit institution (Primary Agricultural Credit Society/ Regional Rural Bank/ Commercial Bank) and self help group are commonly found in each of the villages, with some exceptions.
- There is a wide diversity in crops grown. They include paddy, wheat, sorghum, pearl millet, maize, ragi, chickpea, pigeon pea, green gram, black gram, horse gram, groundnut, sunflower, safflower, castor, sugarcane, onion, vegetables, flowers, banana, tomato, brinjal, chilli, sweet potato, cotton and tobacco.
- Bore wells, open wells and tanks, in that order, are the major sources of irrigation.
- Nearest market to the village is at a distance ranging from 3 km to 40 km.

Special Project Funding:
Bill and Melinda Gates Foundation

Person(s) responsible for this output target
VR Kiresur, KPC Rao, VK Chopde, Y Mohan Rao and GD Nageswara Rao

Output target 2012. 1.10.2 Assembly of secondary agricultural meso-level data into an integrated database updated, expanded in coverage, extended in geographic area and decentralized in level of aggregation

Intermediate output target in 2009: District level database updation

Achievement of Output Target:
 15%
ICRISAT is maintaining district level database for India that includes data on area and production under major crops, land use, crop wise irrigated area, source wise irrigation, farm harvest prices, fertilizer consumption, rainfall, infrastructure variables like road length, and markets, land holding size and census data relating to human and livestock population. The database spans 512 districts in India covering 16 states (now 19 states, with the formation of 3 new states).

A number of research papers have been produced using this database. For example, documenting cropping pattern changes, supply response functions, typology of agriculture, factors influencing livestock density and productivity and more recently on factors influencing diversification of agriculture in India.

Participating Countries:
India and Bangladesh

Participating Partners:
ICRISAT, IRRI, NCAP, CPD

Objectives:
The main objective is to provide one stop shop for meso level database.

Methodology:
The database is being updated every 4-5 years and presently, the data for key variables are available from 1970 to 2004. We are now in the process of updating the database up to 2007-08. Updating the database is a herculean task involving travel to state Directorates of Economics and Statistics, Directorates of Agriculture, Marketing Departments, Animal Husbandry, etc located in each state capital for collection of data from published and unpublished sources. To bring the data to usable form, coding, checking and inputting, processing and merging with existing database, and finally making the database compatible with GIS for spatial analysis etc is being carried out at Patancheru campus.

Progress/Results:
In 2009 district level data on key variables i.e., area and production under major crops, land use, crop wise irrigated area, source wise irrigation, farm harvest prices, fertilizer consumption, rainfall, infrastructure variables like road length, and markets, land holding size and census data relating to human and livestock population were collected for 9 states in India. Data from 2003-2007 were collected from the respective State Directorates of Economics and Statistics, Directorates of Agriculture, and Animal Husbandry, located in each State capital. Following data collection, inputting and validation of data, processing and merging with existing database, making the database compatible with GIS for spatial analysis is on-going. To complement the district level database, state and all-India database on the key variables have also been updated.

Special Project Funding:
Bill and Melinda Gates Foundation

P Parthasarathy Rao and MCS Bantilan

Output target 2012. 1.10.3 Capacity building for NARS scientists and regional scientists in the design and execution of household panel surveys, data processing technologies and time-series panel data analysis

*Intermediate output target in 2009***:** *Regional partners meeting on grant implementation*

After discussions with experts involved in large sample panel data collection as well as those involved in grant implementation it was decided to call a partners meeting among the key players of the proposed VLS project (ICRISAT, NCAP, IRRI, CPD and BRAC) to allow a critical face-to-face meeting to discuss the details of the project implementation plan and involve the active participation of CPD and BRAC (and SocioConsult) in Bangladesh as well as attendance of the PIs from India.

It was noted that data collection at the farm level takes reference to cropping seasons. Expecting a January 2009 project commencement, a planning meeting following the July 2008 face-to-face meeting was deemed important especially to get the research teams commence planning and preparatory work for timely implementation in accordance with the year 1 kharif cropping season. In this connection, it was proposed to call a meeting (in Delhi or Hyderabad) and organize this to discuss the new approaches and required preparatory work.

The first Planning Meeting was held in March 2009. The first day was devoted to project overview by C Bantilan followed by discussions on the Longitudinal Panel Survey in SAT India by KPC Rao, along with perspective sharing on the VLS in East India and Bangladesh by PK Joshi and Sam Mohanty, respectively. This was followed by an extremely lively session on the use of the qualitative component as being complementary to the quantitative element in conducting these studies by Thelma Paris, Alamgir Chowdhury, R Padmaja and Cynthia Bantilan.

As availability of meso data sets for carrying out the project is a very vital aspect, there was a discussion on the availability of updated and expansion of meso-level (state, district, taluka, etc) agricultural data in India and Bangladesh. The discussion focused on meso databases, particularly on increasing the availability of updated and expanded district-level agricultural data for tracking rural poverty. The second day dealt with actions and decisions. It revisited the survey methods that have been used so far in all the three regions. The brainstorming sessions led to zeroing down on the criteria on which additional districts along with the existing ones would be chosen for the study. During the discussions the following criteria were presented.

SAT India:
   • Normal rainfall (600-1000 mm)
   • % irrigated area (20-25%)
   • % area under ICRISAT mandate crops (between 30 and 60%)
   • Soil type (diversity)
   • Infrastructure index (Data source: CMIE, one high one low)
   • Incidence of poverty (% BPL, one high one low)
   • VOP per hectare per capita (in Rs.)
East India:
   • Normal rainfall (1000-2000 mm)
   • % irrigated area (close to state average)
   • % area under rice crops (close to state average)
   • Soil type (diversity)
   • Infrastructure index (Data source: CMIE, one high one low)
   • Incidence of poverty (% BPL, one high one low)
   • VOP per hectare per capita (in Rs.)
Bangladesh:
   • Classify the study area into 3 regions: Favorable, Flood-prone and drought-prone.
   • Select purposively two districts from each region which represent the respective region.
   • From each district, select 8-10 villages from the ongoing study villages.
   • Finally select 2 villages per district, using the qualitative criteria as discussed in the meeting.

In the selection of villages in addition to the 6 traditional VLS villages (12 in SAT India, 12 in East India and 12 in Bangladesh), it was discussed that the sampling of single or twin villages from each identified district depends on the population size and number of households that would be representative of landless, small, medium and large landholding households. In other words, a single village is selected if it is sufficiently large; otherwise twin villages are selected in a district (if there are two small villages in a nearby cluster) such that they together represent the district. In the second case, the following criteria are considered to maintain homogeneity: number of households, social

composition, land holding distribution, percent area irrigated, area under ICRISAT crops (for SAT villages), etc. However, it was also suggested to consider twin village selection such that one of the villages may be is a little more progressive and the other village is a little less progressive.

As it was agreed upon that the qualitative component not only complements but also validates quantitative methods, it was decided that a training of trainers (ToT) would be organized among partners from NCAP, IRRI and ICRISAT on qualitative methods for eliciting information, along with discussions and finalization of survey questionnaires in the last week of April 2009. The planning meeting ended looking forward to the follow-up meeting in Delhi and readiness for project rollout starting May 1

In summary, the March planning meeting discussions were on:
- Criteria for selection of districts and villages
- Sampling of households
- Collaboration and participation
- Data gaps in the District level database for SAT India, East India and Bangladesh
- Harmonization of survey methods and instruments based on lessons from past studies at ICRISAT, India and Bangladesh
- Methodological issues like frequency of data collection, special purpose surveys, number of field investigators
- Emphasis on quality surveys and data analysis.
- Enriching the longitudinal household panel data through use if qualitative tools to track rural poverty and the processes of development
- A sensitization workshop on qualitative tools planned at NCAP, New Delhi during 25-26 April 2009 for key project partners.

Intermediate output target in 2009. *Brainstorming, Sensitization and Planning Workshop: A multidisciplinary, mixed-method approach for examining poverty dynamics*
A two-day brainstorming, sensitization and planning meeting of the ICRISAT-IRRI-Bangladesh- NCAP-India project on Tracking change in rural poverty in household and village economies in South Asia, supported by the Bill and Melinda Gates Foundation was held on 25 and 26 April at the National Center for Agricultural Economics and Policy (NCAP), New Delhi. Samarendu Mohanty and Thelma Paris from IRRI; PK Joshi, Anjani Kumar and other scientists from NCAP; Uttam Kumar Deb from the Center for Policy Dialogue (CPD); Alamgir Chowdhury and Golam Mindia Chowdhury from Socioconsult Bangladesh; BVJ Gandhi from IRRAD; several partners from six states of India; along with Cynthia Bantilan, P Parthasarathy Rao, KPC Rao, VR Kiresur, R Padmaja and the GT–IMPI team from ICRISAT-Patancheru participated in the meeting.

The project aims to contribute to the reduction of the incidence and severity of absolute poverty by markedly increasing the availability of longitudinal district, household, individual and field level data on rural poverty, in terms of both quantity and quality, thus enabling effective evidence based decision making. Besides recapitulating the work done in VLS from 1975, the objective is to exchange ideas and draw upon the expected outputs as part of tracking change in rural poverty over time.

The first day was devoted to discussions on the planning for implementation of the project for selection of districts and villages for village dynamic studies in Bangladesh, SAT India, and East India. The sampling method was agreed upon in order to keep parity across regions. Subsequently depending on the required sample, households would be identified that would be representative of landless, small, medium and large landholder households.

The availability of meso data sets to carry out the project is a very vital aspect.
The close nexus between the micro and macro data sets with each reinforcing the other were reiterated. In this session the discussion was focused on tracking poverty with the help of measurable indicators that can be tracked across time and space. While the choice of indicators depends on the types of data available in India and Bangladesh the following points were noted:
- It is preferable to select few indicators, covering the right questions, at the right level of disaggregation, of good quality, easily measurable within the current capacity.
- Data sources would include both micro- and meso-level data. The micro-data will be collected from the project villages, while meso-level data will cover all of SAT-India, East India and Bangladesh.
- Harmonizing selected indicators across all project regions to the extent feasible to ensure comparability.
The poverty indicators based on primary and secondary data were discussed and finalized. Indicators from secondary data would include extraction of meso level information from large scale household surveys carried out by NSSO and NCAER in India. The Bangladesh team would be revisiting the indicators in the light of further inputs from the team.

The next steps would include:
Step 1: Establish the level of disaggregation of selected indicators, and the frequency of reporting
Step 2: Identify the sources of information that will be used to track each indicator
Step 3: From this list, draw a chart of data collection tools necessary to ensure all indicators are measurable at the time and level selected
Step 4: Compare this chart with the current data collection capacity, identify constraints. Draft a "reasonable" data collection plan
The second day was devoted to discussions on the use of the qualitative approaches and tools. The discussions also identified strategies, methods and tools to ensure that the village dynamic studies are inclusive, from the sampling process, innovations, identification of the roles of men and women in household and farm production system, and realization of men and women empowerment. Several approaches were discussed in tracking rural poverty at the household and community level. These tools and applications will be complementing the current VLS quantitative methods. It was agreed that the qualitative component not only complements but also validates quantitative methods, for eliciting information. A social analysis manual was developed following this meeting.

Survey questionnaires were distributed to all the partners for their feedback to implement in the respective regions. Work plans were developed by each partner to implement in their respective regions. At the end of the second day, the meeting ended in high spirits, with participants eagerly looking forward to project rollout starting 1 May. On 27 April a sub-group from NCAP, ICRISAT and regional partners met to discuss details of activities and outputs under objective 2, i.e, mesolevel database development. NCAP and its partners agreed to implement the plan for selected states in North India and eastern India. ICRISAT will cover southern, western and central India.

MCS Bantilan, P Parthasarathy Rao, VR Kiresur,
Padmaja R and GV Anupama

MTP Project 2: **Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets, Groundnut, Pigeonpea and Chickpea for current and future generations**

Project Coordinator: **HD Upadhyaya**

Executive Summary:

ICRISAT, in partnership with the GCDT (Global Crop Diversity Trust) is assembling 1385 accessions of chickpea, pigeonpea and sorghum from Bangladesh, Kenya, Mali and Nigeria. We assembled 107 of sorghum from USDA. Comparison of our germplasm database with that of the National Institute of Agro-biological Sciences (NIAS), Japan and Regional Genebank, Nairobi identified, 2438 Sorghum (395 from Japan); 201 pearl millet(3 from Japan), 587 Pigeonpea(3 from Japan), 64 chickpea and 17 groundnut lines as unique for ICRISAT. A new software program for bar-coding of germplasm collections has been developed and installed. A data dictionary and data base is under construction.

Geographical data assessment of our existing pearl millet collection, type of vegetation, land cover showed that Nigeria, Burkina Faso, Mali – Mauritania, Chad, and Ghana as major geographical gaps in our collection. Areas for priority collections of chickpea were identified as Hindu Kush-Himalayan region (India, Pakistan, Nepal, and Afghanistan), North-West China, Ethiopia, Uzbekistan, Armenia and Georgia; and for other *Cicer* species, Turkey, Iraq, Iran, Ethiopia and Pakistan. In Groundnut, collections from South America and China are also under-represented. Trait and cluster analysis showed that Eastern and Western Africa followed by Caribbean region are best sources for vegetable pigeonpea.

Two extra-large seeded (100-seed wt. >50g) kabuli chickpea lines ICC 17109 and ICC 17452 (both from Mexico) showed high yield potential and moderate sensitivity to environmental stress. Donor lines for root characters and drought, heat, salinity tolerance and high protein content have been identified. In groundnut several confectionary types (seed weight of 80-90 g/100 seed and yield on par with controls) have been identified.

3198 accessions of sorghum (1695 cultivated and 112 wild), pearl millet (653), chickpea (80), pigeonpea (585) and groundnut (73) for active collection and 8725 accessions of pearl millet (700), chickpea (2971) and groundnut (5054) for duplicate safety back-up at Svalbard Global Seed Vault, Norway were grown. Characterization data were updated for sorghum (146), groundnut (631) and chickpea (52) accessions in addition to 617 newly acquired pearl millet accessions. A total 6352 germplasm samples (6020 from Patancheru and 332 from Niamey) were distributed during the year.

Assembly and conservation of 558 lines of finger millet from Kenya and Uganda; 294 finger millet, 1286 foxtail millet, 395 kodo millet and 296 proso millet lines from NIAS, Japan; 322 finger millet accessions from the Nairobi regional genebank and 359 accessions from AICSMIP, India is in progress.

Databases Analysis of small millets to identify priority geographical area for collection showed that Bangladesh, China, India, Japan and Korea in Asia; Chad in Central Africa; Rwanda, Tanzania and Zaire in Eastern Africa; Angola and Mozambique in Southern Africa; and Cote d' Ivoire in West Africa are under-represented in our small millet collection.

As per the Agreement between ICRISAT and the Nordic Genetic Resources Center, Norway a second batch of 23,000 seed samples were deposited at the Svalbard Global Seed Vault, Norway. This included proso millet (600) and little millet (400) accessions. With these depositions the total number of small millets germplasm at the seed vault increased to 6,400 lines representing finger millet (4,400), foxtail millet (1,000), proso millet (600) and little millet (400). The passport and conservation data on these accessions was successfully uploaded to the public data portal at www.nordgen.org/sgsv.

A total of 679 germplasm samples (finger millet, 129; foxtail millet, 444; proso millet, 34; little millet, 5; kodo millet, 5 and barnyard millet, 62), were dispatched for research use in four countries. 1213 germplasm samples (finger millet, 891; foxtail millet, 318; proso millet,1; little millet,1; kodo millet,1; and barnyard millet,1) were supplied to scientists within the institute. A total of 188 germplasm of small millets were exported to Denmark (30) and France (158).

With the objective of accelerating the utilization of germplasm in crop improvement, composite collections of foxtail millet (500 accessions) have been molecularly profiled using about 19 SSR (Simple Sequence Repeats) markers. A reference set of 200 genetically most diverse accessions was established. Likewise, molecular profiling was done for chickpea (3000 accessions, 50 SSRs), groundnut (1000 accessions, 21 SSRs), pigeonpea (1000 accessions, 20 SSRs), finger millet (1000 accessions, 20 SSRs), pearl millet (1000 accessions, 19 SSRs) and sorghum (3385 accessions, 43 SSRs) to constitute reference sets of about 300 accessions each.

New trait specific donors for most economic characters were identified in chickpea, pigeonpea, groundnut, pearl millet, sorghum and small millets. Drought and salinity tolerance sources as well as donors for stay-green, sweet stalk -high grain & fodder yield, have also been identified. Sources of resistance for Helicoverpa pod borer(Chickpea and pigeonpea), grain mold, leaf blight, rust, anthracnose and downy mildew (sorghum), downy mildew (pearl millet), neck-finger-leaf blast (finger millet) and neck blast (foxtail millet) have been identified. Genotypes with minimum water use for near normal yields under water stress conditions were identified along with optimal root characters in Sorghum and groundnut.

Genotyping datasets for groundnut, pigeonpea, pearl millet, finger millet and foxtail millet composite collections have been made available globally via the internet, http://www.generationcp.org/ . Genetic structure, diversity and allelic richness in a composite collection of chickpea, using SSR markers were published. Regenerated seeds of trait specific (morphological, nutritional and stress resistance) germplasm in chickpea, pigeonpea, groundnut, pearl millet, sorghum, finger millet and foxtail millet were made available to partners on request under SMTA. DNA extracts of the reference sets of chickpea, pigeonpea, groundnut, sorghum and finger millet have been conserved and also supplied to CIRAD on request. Advanced generation interspecific derivatives of A. *hypogaea X A. chiquitana* and A. *hypogaea X kretschmeri* have been derived and hybids between natural and synthetic tetraplods of groundnut were generated.

Drought responsive candidate genes such as CAP2 and promoter, SuSy, SPS, ASR and ERECTA have been identified and sequenced on the chickpea reference set of 300 accessions. An integrated genetic map of an intraspecific cross of chickpea was published in TAG (2009) and

that of an interspecific cross has been developed. A new set of modules for diversity analysis, format parsing and data manipulation with PISE wrappers was published in BMC Research Notes.

A total of 12 agriculturally beneficial micro-organisms (7 bacteria and 5 actinomycetes) were identified by 16s rDNA gene sequence analysis and submitted to NBAIM.

Output 2.1: Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners

Summary:
ICRISAT in partnership with the GCDT (Global Crop Diversity Trust) is developing global conservation strategies for germplasm of its mandate crops and small millets. Assembly and conservation of about 1385 accessions of chickpea, pigeonpea and sorghum regenerated during 2008 in Bangladesh, Kenya, Mali and Nigeria and 107 sorghum lines from USDA is progressing at the regional gene banks in Africa and Patancheru. Comparison of our germplasm database with that of the National Institute of Agro-biological Sciences (NIAS), Japan and Regional Genebank, Nairobi identified, 2438 Sorghum (395 from Japan); 201 pearl millet(3 from Japan), 587 Pigeonpea(3 from Japan), 64 chickpea and 17 groundnut lines as unique for ICRISAT and efforts are underway to assemble these unique collections.

Geographical distribution assessment of existing collections, type of vegetation, land cover showed that Nigeria (62 districts); Burkina Faso (50 districts); Mali and Mauritania (9 districts each), Chad (8 districts), and Ghana (7 districts) as the major geographical gaps in the pearl millet collection at the ICRISAT genebank Areas for priority collections of chickpea were identified. Geographical area of Hindu Kush-Himalayan region (India, Pakistan, Nepal, and Afghanistan), North-West China, Ethiopia, Uzbekistan, Armenia and Georgia are under represented for *C. arietinum* landraces in our collections. *C. reticulatum* and *C. echinospermum* from primary genepool, *C. bijugum* from secondary genepool are identified as a priority for collection in Turkey, Iraq, and Iran. *C. cuneatum* in Ethiopia and wild species in general in Pakistan are also under represented. In Groundnut ssp. *fastiagata* var. *aequatoriana (0.1%)* and var. *peruviana (1.6%)* and ssp. *hypogaea* var. *hirsuta (0.1%)* and wild *arachis* species (2.9%) as a whole are under represented. Collections from South America and China are also under-represented.

Newly acquired accessions of pearl millet (617), sorghum (482) and pigeonpea (178) were characterized and found to possess wide variation for most characters. Diversity analysis showed that Eastern and Western Africa followed by Caribbean region are the best source regions for vegetable pigeonpea.

Several kabuli chickpea lines were identified for traits of economic importance. Two extra-large seeded (100-seed weight >50g) lines ICC 17109 and ICC 17452 (both from Mexico) showed high yield potential and moderate sensitivity to environmental stress. Several heat, drought and salinity tolerant lines were identified. Donor lines for root characters and drought tolerance, and high protein content have been identified. In groundnut several confectionary types (seed weight of 80-90 g/100 seed) and yield on par with controls have been identified.

A total of 3198 critical accessions of sorghum (1695 cultivated and 112 wild), pearl millet (653), chickpea (80), pigeonpea (585) and groundnut (73) for active collection and 8725 accessions of pearl millet (700), chickpea (2971) and groundnut (5054) for duplicate safety back-up at Svalbard Global Seed Vault, Norway were grown. Characterization data were updated for sorghum (146), groundnut (631) and chickpea (52) accessions in addition to 617 newly acquired pearl millet accessions. A total 6352 germplasm samples (6020 from Patancheru and 332 from Niamey) were distributed during the year.

A new software program for bar-coding of germplasm collections has been developed and installed. A data dictionary and data base is under construction.

Output target 2.1.1 New germplasm of staple crops assembled for conservation and utilization (2009)

Output target 2009 2.1.1 Priority areas for sorghum/groundnut for collection and assembly determined in collaboration with NARS and with associated capacity development

Achievement of Output Target:
100%

Participating Countries:
Bangladesh, Japan, Kenya, Mali, Nigeria, and USA

Participating Partners:
GCDT, CIAT and NARS from Bangladesh, Japan, Kenya, Mali, Nigeria and USA

Progress/Results:
ICRISAT is an active partner collaborating with the Global Crop Diversity Trust (GCDT) in developing the global conservation strategies for the germplasm of its mandate crops and small millets. As a follow-up to the earlier meetings, the Trust has developed several regeneration projects around the world (five crops, 49 national collections in 29 countries) for conserving unique global collections. The total number of accessions identified is 17,154 representing sorghum (9535), pearl millet (2551), chickpea (1275), pigeonpea (634) and finger millet (3159). About 1385 accessions of chickpea, pigeonpea and sorghum regenerated in Bangladesh, Kenya, Mali and Nigeria during 2008 are being considered for assembly and conservation at the regional genebanks in Africa and Patancheru.

The passport databases of ICRISAT germplasm was compared with that of the National Institute of Agrobiological Sciences (NIAS), Japan and 395 sorghum and three each of pearl millet and pigeonpea lines were identified as unique for ICRISAT. Similarly the ICRISAT, Patancheru and the Regional Genebank, Nairobi germplasm databases were compared and 2043 sorghum, 198 pearl millet, 64 chickpea 584 pigeonpea and 17 groundnut lines were identified as unique for Patancheru location. These unique collections will be assembled during 2010. Comparing sorghum germplasm database of USDA resulted in identifying 107 accessions unique for ICRISAT which were

subsequently imported and presently being grown in PEQIA (Post Entry Quarantine Isolation Area) for further needful. Comparison with CIAT groundnut germplasm database has resulted in identifying 116 unique lines for ICRISAT.

Country	Districts*
Benin	Banikoara, Bembereke, Gogounou, Kalale, Karimama, Malanville (Borgou).
Burkina Faso	Founzan, Koti (Bougouriba); Boudry, Kogho, Mogtedo, Zam (Ganzourgou); Bogande, Liptogou, Piela, Thion (Gnagna); Gayerie (Gourma); Karankasso-Vigue (Houet); Absouya (Oubritenga); Arbole, Bagare, Bokin, Kirsi, La-Todin, Samba (Passore); Gniaro, Ziou (Nahouri); Bouroum, Yalgo, Zeguedeguin (Namentenga); Dassa, Godyr (Sanguie); Barsalogho, Pensa (Sanmatenga); Boura, Fara, Nilabouri, Silly (Sissili); Gossina, Lankoue, Toma, Ye (Sourou); Diapaga, Logobou, Partiaga, Tambaga (Tapoa); Boussou, Kain, Koumbri, Tangaye, Titao, Zogore (Yatenga); Bere, Gogo, Guiba, Nobere (Zoundweogo).
Cameroon	S. Logone Et-Chari (Province de l'Extrême-Nord); Benoue, Mayo-Louti (Province du Nord).
Central African Rep.	Bamingui, Ndele (Bamingui-Bangoran); Kaga-Bandora (Nana-Gribingui); Batangafo, Kabo (Ouham).
Chad	Djedaa (Batha); Massakory (Chari Baguirmi); Mangalme (Guera); Nokou (Kanem); Doba (Logone Orienta); Kyabe (Moyen-Chari); Abou Deia (Salamat); Lai (Tandjile).
Gambia	Fulladu-East, Wuli (Upper river).

Pearl millet: The ICRISAT Genebank in India holds the world's largest collection of 21,594 pearl millet germplasm accessions from 50 countries, including 18,447 landraces. West and Central Africa (WCA), which was considered as the center of diversity and an important source for resistance to biotic and abiotic stresses of pearl millet. A total of 7,372 landraces were assembled from WCA countries. Of these, 6,434 landraces have the georeference data. The geographic origins of these landraces were analyzed using GIS tools to identify gaps in the collection. Geographical distribution of existing collections, type of vegetation, land cover and the high predicted probability (>70%) for the occurrence of pearl millet in different countries shows that 62 districts in 13 provinces of Nigeria; 50 districts in 16 provinces of Burkina Faso; nine districts in six provinces each of Mali and Mauritania, eight districts in eight provinces of Chad and seven districts in three provinces of Ghana as the major geographical gaps in the pearl millet collection at the ICRISAT genebank (Table 1). It is suggested that the final area for exploration should be decided from the districts identified, prior to the launch of the collection mission in consultation with local government officials and extension officers, who have the knowledge of pearl millet cultivation in the districts identified.

Table 1. Geographical gaps (districts) identified for exploration to collect pearl millet germplasm in West and Central Africa.

Gambia	Fulladu-East, Wuli (Upper river).
Ghana	Nalerigu, Walewale (Northern); Bolgatanga-Tongo, Bongo-Nabdam, Samdemen (Upper east); Nadawli-Funsi, Tumu (Upper west).
Mali	Garganda, Raz-el-Ma, Tilemsi -Lenere (Goundam); Lakamana (Diema); Siby (Kati); Koussane (Kayes); Sebekoro, Sefeto (Kita); Dialloube (Mopti).
Mauritania	Aftout -Barkewoll (Assaba); Aleg, Magta-Lahjar (Brakna); M Bout (Gorgol); Ould-Yenge, Selibaby (Guidimaka); Kobenni, Tintane (Hodh el Gharbi); Moudjeria (Tagant).
Niger	Loga (Dosso); Dakoro (Maradi); Illela, Tchin-Tabaraden (Tahoua); Ouallam (Tillaberry); Tanout (Zinder).
Nigeria	Fufore, Jada (Adamwara); Akko, Alkaleri, Bauchi, Billiri, Dass, Dukku, Gamawo, Gamjuwa, Iama-Are, Itas-Gad, Katagum, Ningi, Kaltungo, Shira (Bauchi); Ngala (Borno); Abujamun (FCT); Babura, Dutse, Garki, Kiyawa, Ringim (Jigawa); Birnin-G, Chikun, Kachia, Kauru (Kaduna); Albasu, Bagwoi, Bunkure, Dawakink, Gabasawa, Gaya, Karaye, Runo, Shanono, Sumaila, Takai, Tudinwad, Wudil (Kano); Musawa, Safana (Katsina); Gurara, Paikoro, Rafi, Shiroro, Wushishi (Niger); Kanam, Keffi, Wase (Plateau); Anka, Bakura, Dange-sh, Goronyo, Gummy, Maradun, Rabah, Sabonbir, Wurno (Sokoto); Karim-La, Lau (Taraba); Bade (Yobe).
Senegal	Kahone (Gossas); Birkelane (Kaffrine); Wack Ngouna (Nio-Durip); Missirah (Tambacounda).
Sierra Leone	Bo, Moyamba (Southern); Portloko, Tonkolili (Northern).
Togo	No gaps

- Names in the parenthesis are provinces

Chickpea: Chickpea passport data was analysed and areas for priority collections were identified. Geographical area of Hindhu Kush-Himalayan region (India, Pakistan, Nepal, and Afghanistan), West and north China, Ethiopia, Uzbekistan, Armenia and Georgia are under-represented for *C. arietinum landraces* in chickpea germplasm collections. *C. reticulatum* and *C. echinospermum* from primary genepool, *C. bijugum* from secondary genepool identified as a priority for chickpea collection in West, South and Southeastern Turkey, Northern Iraq, Northeastern Iran areas. *C. cuneatum* in Ethiopia and wild species in general in Pakistan are also under represented in the chickpea collection

Groundnut: Groundnut data was analyzed and gaps for priority collection were identified. Groundnut ssp. *Fastiagata* var. *aequatoriana* (0.1%) and var. *peruviana* (1.6%) and ssp. *hypogaea* var. *hirsuta* (0.1%) are underrepresented in ICRISAT groundnut collection. Wild *arachis* species (2.9%) as a whole are also underrepresented in ICRISAT groundnut collection. South America, the center of diversity, and China, a major groundnut producing country are also under-represented in ICRISAT groundnut collection

HD Upadhyaya and CLL Gowda

Output target 2.1.2 Assembled germplasm of staple crops characterized for utilization (2009)

Sorghum germplasm from USDA, pearl millet collections from Niger (400 accessions), and pigeonpea collections from Tanzania, Uganda and Mozambique (200 no's) characterized (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pearl millet: Pearl millet germplasm accessions identified as unique in genebank at ICRISAT, Niamey, Niger, were planted in PEQIA for inspection for exotic diseases and subsequently disease free material (617 samples) was released from Indian Plant Quarantine services. New samples were registered by assigning ICRISAT accession number (IP no.). Newly added accessions were characterized in an augmented design with systematically arranged checks (IP 3616, IP 17862 and IP 22281), one check after every 9 test accessions during 2009 rainy season. Each accession was planted in two rows, 4 m long each. Spacing between rows was 75 cm and between plants 10 cm. Crop stand was good and data was obtained from all accessions. The data revealed considerable diversity for almost all traits in the collection. Days to 50% flowering ranged from 56 to 113 days, plant height varied from 205 to 445 cm. Total tillers varied from 1 to 5 and productive tillers from 1 to 3. The major yield components such as panicle length ranged from 14 to 120 cm, panicle thickness from 12 to 40 mm and panicle density score from 4 to 8. Data reveals that the material received is a good source for long and thick panicles.

Pigeonpea: Pigeonpea germplasm collected in Tanzania, Uganda and Mozambique and assembled at ICRISAT, genebank, Niamey, Kenya were acquired through Indian Plant Quarantine Services. After detaining a total of 133 samples in laboratory, a total of 178 samples were grown in PEQIA for inspection and subsequent release to ICRISAT for conservation and utilization. Most of the samples showed late maturity. Severe wilt and phytophthora infection was found. Disease free material will be released to ICRISAT for conservation and utilization.

Sorghum: 482 newly assembled sorghum germplasm accessions from Niger were characterized and classified for important morph-agronomic characters during 2008-2009 post-rainy season. Wide range of variation was observed for days to 50% flowering, plant height (cm), plant pigmentation, basal tillers number, nodal tillering, midrib color, panicle exsertion (cm), panicle length (cm), panicle width (cm), panicle compactness and shape, glume color, glume covering, seed color, 100 seed weight (g), endosperm texture, seed luster, seed subcoat and classified into races and intermediate races. The newly assembled accessions were classified into taxonomic races: Bicolor (59 accessions), Guinea (40 accessions), Caudatum (43 accessions) and Durra (24 accessions), and intermediate races Guinea-caudatum (78 accessions), Caudatum-bicolor (130 accessions), Durra-bicolor (8 accessions), Kafir-caudatum (2 accessions) and Durra-caudatum (98 accessions). 106 newly acquired sorghum accessions received from USDA, Griffin, USA were grown in PEQIA during 2009-2010 post-rainy season.

Groundnut: 186 newly assembled groundnut germplasm lines from USDA, Griffin, USA were grown during 2009-2010 postrainy season in PEQIA for observations and subsequent release by National Bureau of Plant Genetic Resources (NBPGR), India

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda and RP Thakur

Output target 2.1.3 Germplasm sets of staple crops evaluated for useful traits (2009)

Vegetable type pigeonpea germplasm evaluated for agronomic performance (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pigeonpea (*Cajanus cajan* (L.) Millsp.) seed harvested while it is green is a nutritious vegetable and forms a substitute for green pea (*Pisum sativum*). Using the characterization data of more than 12,000 accessions conserved at ICRISAT genebank, Patancheru, India, 105 accessions were selected for vegetable pigeonpea traits (green pod length >6 cm, seeds per pod >5 and 100-seed weight >15 g) and evaluated for vegetable traits during 2007-08. From initial evaluation, a total of 51 accessions were selected and evaluated further during 2008-09, to identify most promising vegetable pigeonpea accessions. Twenty six accessions for pod length, 27 accessions for seeds per pod and seven accessions for 100-seed weight were found to be superior to the best control. ICP 13831 produced longest pods (10.3 cm), ICP 13828 had maximum number of seeds per pod (5.9) and ICP 12746 produced larger green seeds (33.2 g 100 seeds^{-1}). Highest percent of total soluble sugars (9.7%) was recorded in green seeds of ICP 13413. Cluster analysis based on scores of first five Principal Components (PCs) resulted in two clusters that differed significantly for days to 50% flowering, days to 75% maturity, seeds per pod, pod shelling percent, dry pod number per plant, dry pod yield per plant, dry seed yield per plant, total soluble sugars (%) and protein content (%) in green seeds. Major traits of vegetable pigeonpea (pod length, seeds per pod and total soluble sugars) had shown strong positive correlation. Eastern and Western Africa followed by Caribbean region was found as the best source regions for vegetable pigeonpea. Multilocation evaluation of selected accessions was suggested to identify vegetable pigeonpeas suitable for different regions/countries.

HD Upadhyaya and CLL Gowda

Sets of germplasm in staple crops evaluated to identify sources for yield and other quality traits (Annual)

Achievement of Output Target:
100%

Progress/Results:
Chickpea
Early maturity: Most breeding programs aim at developing early-maturing cultivars whose maturity period matches with the available cropping duration. Appropriate time to flowering is a major component of crop adaptation, particularly in the environments where the growing season is restricted by terminal drought and high temperature. Breeding for early maturing, high-yielding and agronomically broad-based cultivars require diverse sources of early maturity. When 17 germplasm lines were evaluated along with four controls (ICCV 2, ICCV 92944, ICCV 96029, and Annigeri) under irrigated, non-irrigated and late sown-irrigated environments, ICC 5597, ICC 11916, ICC 12426 and ICC 14368 (95 to 98 days to maturity; 1.93 -2.21 t ha^{-1} seed yield) among desi and ICC 14197 an early maturing, (91 days to maturity), high yielding (1.73 t ha^{-1} seed yield) and large-seeded (39.8g 100 seed^{-1}) line among kabulis were early maturing and produced higher seed yield than the best controls (Annigeri 101 days to maturity; 1.89 t ha^{-1} or ICCV2, 90 days to maturity, 1.55 t ha$^{-1,}$ 21.8g 100 seeds^{-1}) under irrigated environment. ICC 13889 (84 days to maturity; 1.41 t ha^{-1}) was early maturing and produced higher seed yield under un-irrigated environment in comparison to best control cultivar Annigeri (88 days to maturity; 1.40 t ha^{-1}). ICC 5597 and ICC 12670 (23.3 – 23.9 kg ha^{-1} day^{-1}) were early maturing and produced higher seed yield than Annigeri (23.1 kg ha^{-1} day^{-1}) under late sown environment. ICC 5597, ICC 11916, ICC 12426, and ICC 14368 on an average produced similar seed yield (19.1 – 19.3 kg ha^{-1} day^{-1}) in three environments compared to best control cultivar Annigeri (19.3 kg ha^{-1} day^{-1}).

Large seed size in Kabuli type: Seed size is an important trait in kabuli chickpea. Large seeded (100-seed weight >40g) kabuli chickpeas fetch higher market price as they are preferred by consumers. We evaluated 65 large seeded kabuli lines and four control cultivars (ICCV2, KAK 2, JGK 1 and L 550) in 3 sets. To identify high yielding, and stable-yielding kabuli germplasm lines, these accessions were evaluated from 1999-2000 to 2008-2009 in 18 trials and 13 environments, for 22 qualitative and quantitative characters. Cluster analysis on first three principal components was performed to identify trait-specific genetically diverse germplasm lines for utilization in crop improvement programs. Several highly significant correlations were observed in all three sets and a few large seeded high yielding lines with stability of yield across environments were selected (Table 2).

Several kabuli lines were identified for traits of economic importance (Table 3). Two extra-large seeded (100-seed weight >50g) lines ICC 17109 and ICC 17452 (both from Mexico) showed high yield potential and were moderately less sensitive to environmental stress. The small seeded control cultivars, though high yielding, were highly unstable, performing better only in the favorable environments. This study has also shown that some of the vegetative characters are more susceptible to stress than yield and yield components, hence selection in unfavorable environments should be based on grain yield and its components.

Table 2. Yield, yield components and stability of the best large seeded kabuli chickpea genotypes, across environments in three sets.

Set	Genotype	DF	PN	SW	YKGH	PROD	b=1	S2d=0	PC 1	PC 2
I	14190	59.8	26.6	37.4	1430	13.64	0.70	6869	-1.51	1.69
	14194	37.1	31.2	51.3	1210	11.77	1.48	3638	2.28	-1.18
	7344	36.3	27.3	54.1	1169	10.74	0.76	3606	1.84	-1.56
	17109	35.0	23.6	63.0	1154	10.76	0.77	72420**	2.38	-2.90
	L 550	61.1	43.4	19.7	1413	12.90	1.44	-12867**	-2.02	5.84
	KAK 2	37.5	40.8	39.8	1294	15.23	1.12	-4994	3.12	2.01
	LSD (5%)	2.9	8.2	3.2	271	2.53				
II	17457	49.9	15.0	49.5	1856	17.64	1.11	58536**	1.24	1.89
	17452	35.7	17.6	54.0	1644	16.24	0.71	1456	1.31	-0.22
	19189	32.4	17.3	50.7	1549	15.66	0.69	-4726	0.41	1.37
	19192	35.3	14.7	56.6	1312	12.70	0.85	2791	1.35	-0.67
	KAK 2	35.6	19.0	37.7	1730	17.87	1.10	-16502**	-5.66	-5.05
	L 550	60.6	33.0	20.5	1671	14.93	1.18	338296**	1.15	-2.97
	LSD (5%)	1.6	5.0	2.3	207	2.08				
III	7345	35.0	19.3	48.2	1352	12.69	0.84	-7901	3.80	-0.28
	7347	41.1	16.1	50.7	1105	9.19	1.23	-6734	1.58	-2.44
	11803	59.4	18.1	60.7	890	7.16	0.83	75043**	-1.98	-0.99
	L 550	60.9	40.6	19.1	1544	13.33	1.41	42854**	-1.02	7.69
	KAK 2	36.7	23.4	37.9	1263	12.57	0.90	152259**	3.58	2.00
	LSD (5%)	2.5	6.0	2.4	233	2.12				

Note: ** indicates the significant deviation of S^{2}d from 0;   # completely resistant to Fusarium wilt
DF, days to 50% flowering; PN, pods plant^{-1}; SW, 100-seed weight (g); YKGH, grain yield (kg ha^{-1}); PROD, productivity (kg ha^{-1}day^{-1});
b$_i$, linear response; S^{2}d$_i$, non-linear response; PC, principal component score

Table 3. Kabuli chickpea germplasm lines with characters of importance in different sets.

Set	Cluster	Genotypes (ICC no)	Significantly high for	Significantly low for
I	I	14204,14199,15331,14190,14238, 16674,16744,13787,14926,11303	DF, DM,PH, PW	PN, PROD
	II	L 550, KAK 2,JGK 1, ICCV 2	BPB, PN, YKGH, PROD	FD, DGF, SW
	III	17109, 14194, 14205, 8155, 16670, 7344	FD, DGF, SW	BPB, PN, YKGH, PROD
II	I	ICCV 2, JGK 1, KAK 2, 17458, 17457	APB,PP,YKGH, PROD	PW,DM,DGF,BSB TB,SW
	II	19195, 19196,19192,19193, 19191, 18591, 19194,17452,17456, 17450, 17459, 19189	FD,DGF,SW	DF,ASB,
	III	L 550,19190,19188	DF,DM,BPB,BSB, ASB,TB,	SW,YKGH,PROD
III	I	14201,11883,14196,11821, 11745, 16790,11295,16819,7713,16821, 14361,14207,14193,11815, 7346, 8151,14214, 6243, 16803,11816, 16750, 6210	DF, DM, PLHT, PLWD	YKGH, PROD
	II	14203,12033,14195,13821, 8156, 14206,14188, 7347	FD, DGF, SW	PN, APB
	III	L 550, KAK 2, JGK 1, ICCV 2, 14197, 7345, 6187	PN, YKGH, PROD	SW, FD, DF, DM

APB, apical primary branches (number); ASB, apical secondary branches (number); BPB, Basal primary branches (number); BSB, Basal secondary branches (number); DF, days to 50% flowering; DFG, grain filling duration (days); DM, days to maturity; FD, flowering duration (days); PH, plant height (cm); PN, pods plant[-1] (number); PROD, productivity (kg ha^{-1}day[-1]); PW, plant width (cm); SW, 100-seed weight (g); TB, tertiary branches (number); YKGH, grain yield (kg ha^{-1})

Heat tolerance in chickpea: Heat stress due to increased temperature is one of the important limiting factors for crop production in many areas across the world. Transitory or constant high temperatures cause an array of morpho-anatomical, physiological and biochemical changes in plants that affect plant growth and development, which lead to a drastic reduction in economic yield. Developing crop plants with improved thermo tolerance using various genetic approaches can diminish the adverse effects of heat stress. When 17 germplasm lines and controls (KAK 2, ICCV 92944, and Annigeri) were evaluated under irrigated, non-irrigated and late sown irrigated environments, ICC 13124 and ICC 19645 (1.89 - 1.91 t ha^{-1}) in irrigated environment; ICCs 14649, 14653 and 19641 (1.32-1.36 t ha^{-1}) in non-irrigated environment; and ICC 14293, ICC 14649, ICC 14653, and ICC 19645 (1.82-1.92 t ha^{-1}) in late sown irrigated environment performed better than the best heat tolerant control cultivar ICCV 92944 (1.79 t ha^{-1} in irrigated; 1.28 t ha^{-1} in non-irrigated; and 1.58 t ha^{-1} under late sown irrigated). ICC 7410, ICC 14284, ICC 14293, ICC 17456, ICC 17458 and ICC 18591 flowered early under late sown condition (high temperature). ICC 7410, ICC 13124, ICC 14284, ICC 14293, ICC 14649 and ICC 17459 have consistent 100-seed weight in all three environments. ICCs 14284, ICC 14293, ICC 14649, ICC 14653, ICC 19641 and ICC 19645 were stable in seed yield in all three environments revealing their capability to perform well under high temperature conditions (Table 4).

Table 4. Performance of heat tolerant chickpea germplasm lines under normal and late sown irrigated environments for key agronomic traits.

Sl no.	Genotype	Days to 50% flowering		Days to maturity		100-seed weight(g)			Plot yield (kg ha^{-1})		
		Normal sown	Late sown	Normal sown	Late sown	Normal sown	Late sown	% of normal sown	Normal sown	Late sown	%of normal sown
1	ICC 14284	43	34	101	83	27	29	107	1812	1747	96
2	ICC 14293	44	34	103	83	27	30	111	1881	1840	98
3	ICC 14649	42	34	101	82	30	31	103	1863	1822	98
4	ICC 14653	40	35	102	82	29	31	107	1848	1904	103
5	ICC 19641	43	38	98	82	11	11	100	1738	1779	102
6	ICC 19645	43	41	100	82	15	13	87	1553	1929	124
Heat tolerant control											
7	ICCV 92944	43	35	96	79	21	21	100	1793	1582	88

Performance of drought tolerant kabuli chickpea: Drought is a major constraint to chickpea production. Root traits have been identified to postpone dehydration under moisture stress. Root length and maximum root depth positively influence the seed yield under drought conditions. We evaluated 51 large-seeded kabuli accessions with high root length density, a trait related to drought tolerance, for agronomic and yield related traits. ICC 8151, ICC 11816, ICC17457 (1.57 – 2.09 t ha^{-1}) produced significantly higher seed yield and 100-seed weight (36-51g) than the drought tolerant control ICC 4958 (35g, 1.25 t ha^{-1}).

Performance of salinity tolerant chickpea: Salinity is an important constraint in agriculture worldwide, especially in South Asia (India, Pakistan) and Australia. Improved genotypes that are well adapted to saline conditions are needed to enhance and sustain production in these areas. We evaluated 13 previously identified salinity tolerant chickpea germplasm accessions and seven control cultivars under irrigated and non-irrigated environments for yield and yield attributing traits. Salinity tolerant accessions ICC 4495, ICC 8950, ICC 9242, and 15996 produced higher seed yield (3178 - 3585 kg ha^{-1}) compared to the best salinity tolerant control cultivar CSG 8962 (2978 kg ha^{-1}) under irrigated environment. Similarly ICC 67, ICC 867, ICC 4495, ICC 5003, ICC 8950, ICC 12155, and ICC 15996 produced higher seed yield (1963 – 2178 kg t ha^{-1}) compared to CSG 8962 (1711 kg ha^{-1}) under non-irrigated environment. On average ICC 867, ICC 2580, ICC 4495,

ICC 5003, ICC 8950, and ICC 15996 produced higher seed yield (2397 – 2881 kg ha^{-1}) compared to CSG 8962 controls (2344 kg ha^{-1}) (Table 5).

Table 5. Performance of salinity tolerant germplasm lines under irrigated and non-irrigated environment at ICRISAT Patancheru, 2008-2009.

Sl no	Genotype	Seed yield (kg ha^{-1})			Productivity (kg ha^{-1}day[-1])		
		Irrigated	Un-irrigated	Pooled	Irrigated	Un-irrigated	Pooled
1	ICC 867	2988.6	2093.0	2540.8	28.5	24.1	26.3
2	ICC 2580	2998.6	1794.8	2396.7	28.1	20.7	24.4
3	ICC 4495	3539.4	2120.5	2829.9	33.3	27.4	30.3
4	ICC 5003	3174.0	2060.5	2617.2	30.0	23.6	26.8
5	ICC 8950	3330.7	1962.6	2646.6	31.6	22.3	26.9
6	ICC 15996	3584.7	2177.6	2881.1	36.3	25.1	30.7
Control							
8	CSG 8962	2977.5	1710.8	2344.1	28.3	19.3	23.8
9	JG 11	3367.9	1977.2	2672.5	33.0	22.4	27.7
10	JG 62	3027.9	1841.7	2434.8	30.7	21.9	26.3
11	L 550	2533.2	1919.6	2226.4	23.4	21.6	22.5
12	ICCV 2	2453.3	1613.7	2033.5	26.2	18.8	22.5
13	**ICCV 96029**	1676.6	1569.9	1623.2	18.8	20.4	19.6
14	JUMBO 2	2078.4	1543.7	1811.0	19.4	18.7	19.0
Mean		2864.30	1871.20	2363.00	27.50	21.60	24.50
SE (±)		188.85	176.00	142.80	1.85	2.53	1.81
CV (%)		10.01	15.41	11.85	10.21	21.41	15.08

Root length density and chickpea yield: Extensive and deep roots have been recognized as one of the most important traits for improving chickpea productivity under receding soil moisture conditions. We evaluated 10 accessions each of small and large root length density along with controls (ICC 4958, Annigeri, and ICCV 2) under irrigated and non-irrigated conditions. ICC 2072, ICC 10945, ICC 11198, and ICC 15868 among low root density (2.45 – 2.64 t ha^{-1}) and ICC 8261 (1.95 t ha-1) among high root length density produced higher seed yield under irrigated environment and ICC 10945(2.02 t ha^{-1}) produced similar seed yield to the best drought tolerant control cultivar ICC 4958 (2.09 t ha^{-1} irrigated; 2.18 t ha^{-1} non-irrigated) under non-irrigated environment.

Evaluation of deep root length chickpea lines for yield: Root depth is also a drought tolerance related trait in chickpea. We evaluated 10 accessions each of very deep rooted and shallow rooted along with ICC 4958, Annigeri, and ICCV 2 as control cultivars under irrigated and non-irrigated conditions. ICC 95 (3.1 t ha^{-1}) a very deep rooted accession produced similar seed yield to the best deep rooted control cultivar ICC 4958 (3.1 t ha^{-1}). Similarly, ICC1356 (3.0 t ha^{-1}) a shallow rooted accession produced similar seed yield to ICC 4958 (3.1 t ha^{-1}) under non-irrigated environment.

Evaluation of chickpea mini core for agronomic traits: Evaluation of 211 chickpea germplasm lines and five control cultivars (desi - Annigeri, G130 and ICCV10; kabuli - L550 and KAK 2) under normal and high temperature environments (sown in the first week of February to expose the crop to high temperatures in March/April) during 2008-09 post-rainy season at Patancheru and under normal environment at UAS Dharwad. At ICRISAT Patancheru under normal environment 10 desi (2.7-3.0 t ha^{-1}) and 8 kabuli accessions (2.1 to 3.3 t ha^{-1}) produced greater seed yield than respective control cultivars, Annigeri (2.4 t ha[-1)], G 130 (2.1 t ha^{-1}) , ICCV 10 (2.5 t ha^{-1}), L550 (2.3t ha^{-1}), KAK 2 (2.01 t ha^{-1}). ICC 15510, ICC 8318, ICC 15610, ICC 3946, ICC 5383 (2.5-3.0 t ha^{-1}) among desi types and ICC 15435, ICC 9137, ICC 10885(2.4 – 3.3 t ha^{-1}) among kabuli types were the best high yielding accessions. ICC9137, ICC 11764, and ICC 15518 were the best large seeded kabuli accessions (38-40g). ICC 8318, 14595, and 16374 were the earliest flowering lines (37-43 days) under normal environment at Patancheru. Under high temperature environment at Patancheru 13 desi (2.3- 3.1 t ha^{-1}) and 5 kabuli accessions (2.1 to 3.0 t ha^{-1}) produced higher seed yield than respective control cultivars Annigeri (2.34 t ha^{-1}), G 130 (2.31 t ha^{-1}), ICCV 10 (2.25 t ha^{-1}), L550 (2.12 t ha^{-1}) and KAK 2 (2.05 t ha^{-1}). ICC 15510, ICC 8318, ICC 15612, ICC 15868, and ICC 16915 (2.6 – 3.1 t ha^{-1}) among desi types and ICC 15435, ICC 9137, and ICC 10885 (2.5 – 3.0 t ha^{-1}) among kabuli types were the best lines under high temperature environment at Patancheru. Under normal environment at UAS Dharwad a total of 12 (2.1-3.3 t ha^{-1}) desi and 4 (2.1 to 2.8 t ha^{-1}) kabuli type accessions produced higher seed yield than respective control cultivars Annigeri (2.4 t ha^{-1}), G 130 (2.8 t ha^{-1}), ICCV 10 (2.2 t ha^{-1}), L550 (2.05 t ha^{-1}), and KAK 2 (2.10 t ha^{-1}). ICC 15510, ICC 8318, ICC 2969, ICC 2580, and ICC 8384 (2.4 – 3.3 t ha^{-1}) among desi type and ICC 15435, ICC 12037, ICC 7272, ICC 10885, and ICC 15406 (2.1 - 2.8 t ha^{-1}) among kabuli types were the best accessions. ICC 8318, ICC 9590, ICC 14595, ICC 15518, and ICC 16374 were the earliest flowering lines (35- 38 days) under normal environment at Dharwad. ICC 8318 flowered early (34-37 days) and produced high seed yield (2.9 – 3.1 t ha-1) under all three environments.

Resistance to pod borer (*Helicoverpa armigera*) in mini core collection: Evaluated 211 mini core accessions along with a resistant (ICC 506-EB) and a susceptible (L 550) control cultivar for resistance to pod borer in a randomized complete block design during the 2008/09 postrainy season. Data were recorded using detached leaf assay method at the vegetative (30 days after seedling emergence) stage. The terminal branches (5-7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 to 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

A total of 23 mini core accessions performed better (score ≤ 3.0) than the resistant control cultivar ICC 506-EB (3.1) for leaf feeding score. The best five lines were ICC 16903, ICC 6877, ICC 3946, ICC 12028, and ICC 11764 for leaf-feeding (score1.3.-2.3) under detached leaf assay screening as compared to ICC 506-EB (3.1). Forty mini core accessions had lower larval survival rate (37 to 60%), compared to resistant control cultivars ICC 506-EB (63%). The best five accessions for least larval survival rate were ICC 12537, ICC 7819, ICC 13764, ICC 16903, and ICC 14831 (37- 47%). A total of 15 accessions showed lower larval weight (1.2 to 2.2 mg larva^{-1}) compared to resistant control cultivar ICC 506-EB (2.3 mg larva^{-1}). ICC 16903, ICC 6877, ICC 3946, ICC 12028, and ICC 11746 were the best five accessions for lower larvae weight (1.2-2.0).

Evaluation of chickpea mini core for protein content: Crude protein content was higher in 35 (20.13 - 29.98%) mini core accessions than in Annigeri (19.99%), G 130 (22.11%), ICCV 10 (20.47%), L 550 (22.12%) and KAK2 (20.87%). ICC 1061, ICC 2277, ICC 3218, ICC 3421, and ICC 13441 (26.79-29.98%) were the best five mini core accessions with high protein content.

Evaluation of chickpea mini core for drought tolerance: Mini core was evaluated for drought avoidance root traits: root length density (RLD) and plant dry weight (PDW) to RLD (PDW/RLD) ratio as a part of chickpea reference set during 2008-09 postrainy season.

Plant Dry Weight (PDW): PWD was higher in 9 (2.4-2.7) mini core accessions compared to control cultivars Annigeri (2.24 g), G 130 (1.84 g), ICCV 10 (1.79 g) KAK 2 (2.4), and L 550 (1.97 g). ICC 15435 ICC 8350, ICC 13077, ICC 8261, and ICC 15518 (2.5 - 2.6 g) were the best lines with highest PDW.

Root dry weight (RDW): RDW was higher (0.806 to 1.069 g) in 17 mini core accessions compared to control cultivars Annigeri (0.746 g), G 130 (0.805g), ICCV 10 (0.706 g), KAK 2 (0.742) and L 550 (0.687 g). ICC 15435, ICC 8261, ICC 13599, ICC 10885, and ICC 8384 (0.953 to 1.069 g) were five lines with high RDW.

Root depth (RD): RD was greater (130-150 cm) in 13 mini core accessions compared to control cultivars Annigeri (120 cm), G 130 (110 cm), ICCV 10 (123 cm), KAK 2 (130cm), and L 550 (115 cm). ICC 7819, ICC 283, ICC 8740, 12916, and ICC 1098 were the best accessions with maximum root depth (130-150cm)
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RDW to total dry weight (TDW, which is sum of RDW and shoot dry weight) ratio(%): RDW to TDW ratio was higher in 6 (31.6 - 35.0%) mini core accessions compared to control cultivars Annigeri (28.1%), G 130 (31.5%), ICCV 10 (28.6%), KAK 2 (25.6%), and L 550 (31.0%). The best five accessions with highest RWD/TDW ratio were ICC 1098, ICC 8384, ICC 11584, ICC 13441, and ICC 9002 (32 – 35%).

Root surface area (RSA): RSA was higher (1204.5 – 1270.2 cm^2) in 8 mini core accessions compared to control cultivars Annigeri (1081.4 cm^2), G 130 (1200.6 cm^2), ICCV 10 (834.9 cm^2), KAK 2 (1116.9 cm^2), and L 550 (871.9 cm^2). ICC 9643, ICC 15435, ICC 10885, ICC 8384, and ICC 13599 (1210.6 – 1270.2 cm^2) were the best reference accessions with maximum RSA.

Root volume (RV): RV was higher (17.2 – 22.2 cm^3) in 9 mini core accessions compared to control cultivars Annigeri (15.6 cm^3), G 130 (17.1 cm^3), ICCV 10 (12.3 cm^3), KAK 2 (17.0), and L 550 (12.7 cm^3). ICC 8384, ICC 9402, ICC 15435, ICC 1194, and ICC 13599 (20.0 - 22.2 cm^3) were the best five reference accessions with maximum root volume.

Evaluation of chickpea reference set for agronomic traits: Evaluation of 293 chickpea reference set lines and five control cultivars (desi - Annigeri, G130 and ICCV10; kabuli - L550 and KAK 2) in alpha design under normal and high temperature environments during 2008-09 post-rainy season at Patancheru, India and under normal environment at UAS Dharwad. At Patancheru under normal environment 19 desi (2.7-3. 3 t ha^{-1}) and 12 kabuli accessions (2.1 to 3.2 t ha^{-1}) produced greater seed yield than respective control cultivars Annigeri (2.4 t ha^{-1}), G 130 (2.1 t ha^{-1}) , ICCV 10 (2.5 t ha^{-1}), L550 (2.3t ha^{-1}), KAK 2 (2.01 t ha^{-1}). ICC 15510, ICC 8318, ICC 15610, ICC 3946, and ICC 5383 (3.0-3.3 t ha^{-1}) among desi types and ICC 15435, ICC 9137, ICC 10309, ICC 10569, and ICC 19100 (2.7 – 3.2 t ha^{-1}) among kabuli types were the best high yielding accessions. ICC 11303, ICC 18724, ICC 18983, 19165, and ICC 20266 were the best large seeded kabuli accessions (40-53g). ICC 8318, ICC 9590, ICC 14595, ICC 15518, and ICC 16374 were the earliest flowering lines (38-45 days) under normal environment at Patancheru. Under high temperature environment at Patancheru 29 desi (2.35-2.97 t ha^{-1}) and 14 kabuli type accessions (2.07 - 3.27 t ha^{-1}) produced higher seed yield than respective control cultivars Annigeri (2.34 t ha^{-1}), G 130 (2.31 t ha^{-1}), ICCV 10 (2.25 t ha^{-1}), L550 (2.12 t ha^{-1}) and KAK 2 (2.05 t ha^{-1}). ICC 15510, ICC 8318, ICC 8384, ICC 5639, and ICC 4991(2.7 – 2.97 t ha^{-1}) among desi types and ICC15434, ICC 3410, ICC 9137, ICC 10885, and ICC 15802 (2.90 – 3.27 t ha^{-1}) among kabuli types were the best high yielding under high temperature environment at Patancheru. Under normal environment at UAS Dharwad, 28 (2.8-3.3 t ha^{-1}) desi and 14 (2.09 - 3.3 t ha^{-1}) kabuli type accessions produced higher seed yield than respective control cultivars Annigeri (2.4 t ha^{-1}), G 130 (2.8 t ha^{-1}), ICCV 10 (2.2 t ha^{-1}), L550 (2.05 t ha^{-1}), and KAK 2 (2.10 t ha^{-1}). ICC 15510, ICC 8318, ICC 8384, ICC 2969, and ICC 4567 (2.9–3.3 t ha^{-1}) among desi type and ICC 15435, ICC 3410, ICC 12037, ICC 7255, and ICC 9137 (2.7 – 3.3 t ha^{-1}) among kabuli types were the best high yielding accessions. ICC 8318, ICC 9590, ICC 14595, ICC 15518, and ICC 16374 were the earliest flowering lines (35-38days) under normal environment at Dharwad. ICC 8318 flowered early (34-37 days) and produced high seed yield (2.9 – 3.1 t ha^{-1}) under all the three environments.

Evaluation of chickpea reference set for protein content: Crude protein content was higher (20.13 to 30.28%) in 161 reference set accessions than in Annigeri (19.99%), G 130 (22.11%), ICCV 10 (20.47%), L 550 (22.12%) and KAK2 (20.87%). ICC 1161 ICC9418, 11903, ICC 13719, ICC 20174, and ICC 20193 (27.47-30.28%) were the best five accessions with higher protein content.

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Groundnut
Evaluation of confectionary germplasm: Twentyfive large seeded accessions and five control cultivars (Gangapuri, ICGS 44, ICGS 76, and Somnath) were evaluated during 2008-09 postrainy season at Patancheru. ICG 6811, ICG 9127, and ICG 12199 (64-68 g 100-seed^{-1}; 28.5 – 31.8 ka ha^{-1} day^{-1}) produced higher pod yield than all the control cultivars (pod yield 21.3 – 27.3 kg ha^{-1}day^{-1}; 50-76.0 g 100 seed^{-1}). ICG 3311, ICG 4466, ICG 5690, ICG 8268, and ICG 12755 had greater 100 seed weight (81-90g) with productivity (19.4 – 24.3 kg ha^{-1} day^{-1}) similar to the control cultivars.

F12 RILs (TAG 24 x GPBD 4) for rust and late leaf spot: Evaluation of 264 RILs and two parent (TAG 24 and GPBD 4) cultivars during 2008-09 postrainy season for pod yield and other agronomic traits revealed that 14 RILs produced greater pod yield (5.22-5.95 t ha^{-1}) with greater 100 seed weight (42.8 – 57.2g) as compared to the best parent GPBD 4 (5.14 t ha^{-1} pod yield; 42.5g 100 seed^{-1})

Evaluation of groundnut germplasm for agronomic traits: 264 germplasm lines and four control cultivars (Gangapuri, M 13, ICGS 44 and ICGS 76) as part of reference set were evaluated in alpha design during 2008-09 post-rainy season. Forty nine lines (3.85 -6.83 t ha^{-1}) produced greater pod yield than all the controls (2.85 – 3.85 t ha^{-1}). 15 of these 49 are landraces originating from 10 countries (Zimbabwe, Argentina, Indonesia, Zaire, Ecuador, Nigeria, Costa Rica, Bolivia, Peru, and China) (Table 6). ICG 6022, ICG 12276, ICG 14482, ICGV 01232, and ICGV 02266 were the best five lines which produced greater pod yield (4.03 -5.32 t ha^{-1}) and higher seed weight (62-68 g 100-seed^{-1}) in compared to all the control cultivars (2.85 – 3.85 t ha^{-1}; 47-61g 100-seed^{-1}).

Table 6. Performance of groundnut landraces at ICRISAT Patancheru, 2008-09 postrainy season.

Sl no	Genotype	Source country	Botanical variety	Days to 50% flowering	Days to maturity	Pod yield (t ha^{-1})	Shelling (%)	100 seed weight (g)	Productivity (kg ha^{-1} day^{-1})
1	ICG 10092	Zimbabwe	fastigiata	25	120	3.929	71.9	54.8	32.7
2	ICG 5221	Argentina	fastigiata	25	120	4.083	70.7	51.1	33.8
3	ICG 15415	Indonesia	fastigiata	24	131	4.164	68.9	51.1	32.0
4	ICG 15042	Unknown	fastigiata	24	125	4.459	68.2	48.9	35.7
5	ICG 14106	Zaire	fastigiata	25	121	6.827	67.9	45.2	56.7
6	ICG 15419	Ecuador	hirsuta	26	134	5.120	63.2	55.4	38.8
7	ICG 14466	Nigeria	hypogaea	32	140	3.937	69.7	50.5	28.7
8	ICG 15190	Costa Rica	hypogaea	31	138	4.017	68.7	53.0	29.6
9	ICG 14482	Nigeria	hypogaea	32	145	4.034	70.9	67.8	28.5
10	ICG 12276	Bolivia	hypogaea	28	142	4.412	69.7	62.2	31.7
11	ICG 12672	Bolivia	hypogaea	29	141	4.419	64.7	53.6	31.9
12	ICG 11088	Peru	peruviana	29	136	4.679	68.2	48.9	34.8
13	ICG 14985	Unknown	vulgaris	24	135	3.869	68.2	59.8	29.0
14	ICG 10384	Nigeria	vulgaris	27	120	3.933	69.7	43.4	32.7
15	ICG 334	China	vulgaris	27	120	4.039	72.2	48.0	33.5
Control									
16	Gangapuri	India	hypogaea	24	120	2.846	70.2	47.1	23.2
17	M 13	India	fastigiata	31	147	3.519	70.9	61.3	24.6
18	ICGS 44	ICRISAT	vulgaris	29	136	3.850	73.2	59.1	28.6
19	ICGS 76	ICRISAT	hypogaea	30	141	3.554	72.4	56.1	25.6
GM				28.64	130.77	3.311	68.65	48.08	25.61
SEM				0.93	2.39	0.404	2.66	2.57	3.24
CV %				6.03	3.25	24.46	6.72	8.00	24.98

HD Upadhyaya and CLL Gowda

Pearl millet

Climate change is expected to result in high temperature in many parts of the world affecting the pearl millet production. Both plant growth and development are affected by high temperature. The adverse effect of high temperature is acute if it occurs during flowering and grain development. ICRISAT genebank at Patancheru, India holds 21,594 accessions of pearl millet germplasm including 750 accessions of wild relatives from 50 countries. We evaluated the pearl millet mini core collection consisting 238 accessions (1% of entire collection) representing the entire collection of 20,766 accessions at ICRISAT, Patancheru and Central Arid Zone Research Institute (CAZRI), Jodhpur, India, for agronomic traits under non-stress environment (during rainy season 2009). During 2009 rainy season, the experiment was conducted in alpha design using four control cultivars (IP 3616, IP 17862, CZP-IC 923 and CZP 9802). Plant stand and crop growth was good in all accessions. Observations were recorded for days to 50% flowering, days to maturity, plant height, number of total tillers, number of productive tillers, panicle exsertion, panicle length, panicle thickness, panicle compactness, 1000-seed weight, seed colour, seed yield per plot (g), fodder yield per plot (g). Data obtained from 2009 rainy season evaluation is being processed. Preparations are underway for planting the same set under stress conditions at both locations in 2010 summer season. The difference in trait values between normal and high temperature seasons will be recorded and considered as a measure of heat tolerance. The selected heat tolerant and sensitive lines will be further studied. The heat tolerant pearl millet germplasm will be made available to researchers, world wide for use in breeding heat tolerant and for mapping and cloning of genes/QTL associated with heat tolerance.

HD Upadhyaya and CLL Gowda

Sorghum

Sorghum mini core collection (242 accessions) with three control cultivars was evaluated in a replicated trial during 2009 rainy season. 50 grain mold resistant accessions were also evaluated for important morpho-agronomic characters during 2009 rainy season. Wide range of variation was observed for days to 50% flowering, plant height (cm), panicle exsertion (cm), panicle length (cm), panicle width (cm), weight of 5 panicles and 100 grain weight.

100 accessions of wild sorghums were characterized for important morpho-agronomic characters in botanical garden. A wide range of variation was observed for days to 50%flowering, culm height, rooting at culm nodes, culm branching, culm hairiness, culm pigmentation, waxy bloom, nodal hariness, nodal hair type, nodal pigmentation, leaf sheath clasping, leaf shape, leaf color, midrib color, leaf blade color(abaxial and adaxial), leaf margin hairiness, leaf sheath hairiness, ligule form, leaf length (5th leaf) cm, leaf width (5th leaf) cm, panicle exsertion (cm), panicle length (cm), panicle width (cm), rachis node number, plants whether rhizomatous or not, basal tillers number, panicle shape, rachis continuity, number of branches at each node, spikelet pairing and raceme length. 12 wild sorghum germplasm accessions consisting of S. *aethiopicuum* (2), S. *verticilliflorum* (4), S. *Virgatum* (4), and S. *arundinaceum* (2) were also evaluated for assessing their capability to fix biological nitrogen, during 2009 rainy season. The data analysis is in progress.

HD Upadhyaya and CLL Gowda

New/assembled germplasm characterized/evaluated for important traits to fill gaps in characterization data (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Chickpea: Characterized 1048 chickpea accessions to fill the gaps in characterization database for days to 50% flowering, days to flower ending, flower color, plant color, flowering duration, growth habit, and days to maturity during 2008-09 postrainy season.

Groundnut: Characterized 453 groundnut accessions during 2008-09 postrainy and 200 accessions during 2009 rainy season to fill the gaps in characterization database for 31 agro-morphological traits

Pigeonpea During 2008-09, a total of 670 accessions of pigeonpea were characterized to fill the gaps for various traits in characterization database. The gaps were mostly for leaf size. In continuation of our efforts to fill the gaps in characterization database, we have planted another set of 804 accessions in 2009-2010 rainy season in vertisols for recording observations on various characters. Recording of observations is in progress.

Pearl millet: Registered, characterized, and documented 617, pearl millet germplasm accessions identified as unique in genebank at ICRISAT, Niamey, Niger, for 23 morpho-agronomic traits. Data revealed considerable diversity for almost all traits in the newly acquired pearl millet collection. Days to 50% flowering in the newly acquired pearl millet collection ranged from 56 to 113 days, plant height varied from 205 to 445 cm. Total tillers varied from 1 to 5 and productive tillers from 1 to 3, panicle length from 14 to 120 cm, panicle thickness from 12 to 40 mm and panicle density score from 4 to 8.

Sorghum: 482 newly assembled sorghum germplasm accessions from Niger were characterized and classified for important morpho-agronomic characters. These include races Bicolor (59 accessions), Guinea (40 accessions), Caudatum (43 accessions) and Durra (24 accessions), and intermediate races Guinea-caudatum (78 accessions), Caudatum-bicolor (130 accessions), Durra-bicolor (8 accessions), Kafir-caudatum (2 accessions) and Durra-caudatum (98 accessions).

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda and RP Thakur

New germplasm sources identified for target insect pests and diseases in different crops (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Special Project Funding:
NA

Progress/Results:
Identification of new germplasm sources for resistance to ascochyta blight, botrytis gray mold, Fusarium wilt, dry root rot and collar rot in chickpea: Two hundred and fifty new germplasm accessions were evaluated for resistance to ascochyta blight (AB), botrytis gray mold (BGM), Fusarium wilt (FW), collar rot (CR) and dry root rot (DRR) diseases under controlled environment conditions at ICRISAT-Patancheru. Standardized resistance screening techniques based on sound epidemiological principles were followed to evaluate these accessions for individual diseases. Severities of AB, BGM and DRR were scored on 1-9 rating scale and the incidence of FW and CR was recorded as percentage of mortality.

Resistance to AB: Eight lines were found resistant (0.1-3.0) and 87 moderately resistant (3.1-5.0)

Resistance to BGM: Three lines were found resistant and 82 moderately resistant (3.0-5.0).

Resistance to FW: Thirty nine lines were found asymptomatic (0% incidence) and three lines moderately resistant (10.1-20.0% incidence)

Resistance to DRR: One line (ICC 4918) was resistant (0.1-10% incidence) and 14 moderately resistant (10.1-20.0% incidence).

Resistance to CR: One line (ICC 4462) was asymptomatic (0% incidence), one (ICC 4843) resistant (0.1-10%) and three lines moderately resistant (10.1-20.0% incidence) to CR.

<div align="right">Suresh Pande, Mamta Sharma, HD Upadhyaya and CLL Gowda</div>

Evaluation of chickpea germplasm for resistance to pod borer, *Helicoverpa armigera*: A reference set (300 lines), including the resistant (ICC 506), and the susceptible (L 550) controls were evaluated for resistance to pod borer, *Helicoverpa armigera* during the 2008/09 postrainy season at ICRISAT-Patancheru, India. There was no insecticides application in the experimental plots. Data were recorded on leaf and pod damage, egg and larval density per 10 plants, overall resistance score, and grain yield. The material was also evaluated for resistance to *H. armigera* using detached leaf assay at the vegetative (30 days after seedling emergence) stage. For this purpose, the terminal branches (5 – 7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

In detached leaf assay at the vegetative stage (30 days after seedling emergence), leaf feeding scores ranged from 1.67 – 7.98 (mean 3.98), as compared to 3.67 on ICC 506 and ICC 3137. Larval weights ranged from 0.58 – 5.65 mg (mean 2.80 mg) compared to 1.91 mg on ICC 506, and 2.94 mg on ICC 3137. Many lines suffered low feeding damage and also had lower larval weight gains comparable to the resistant check, ICC 506, and further screening of these lines will result in identification of genotypes with antifeedant and/or antibiosis mechanism of resistance to *H. armigera*.

Under natural infestation in the field, leaf feeding scores varied from 3.5 – 7.5 in the reference collection, 5.5 in ICCV 10, and 5.0 in ICC 3137 during the vegetative phase. There were 0.0 – 9.0 larvae per 5 plants in the reference collection, 4.0 in ICCV 10, and 5.5 in ICC 3137. During the reproductive stage, there were 0.0 – 17.0 larvae per 5 plants in the reference collection, 3.5 in ICCV 10, and 6.0 larvae in ICC 3137. Overall resistance scores ranged 3.0- 8.0 (mean 6.25) in the test entries, 3.5 in ICCV 10 and 7.0 in ICC 3137. Pod damage ranged from 3.5 - 86.9% in the reference collection, 12.9% in ICCV 10 and 24% in ICC 3137. The grain yield of the test lines ranged from 100 – 2,530 kg ha^{-1}, The genotypes showing lower susceptibility to damage by *H. armigera* and a yield potential of >1,000 kg ha^{-1} under unprotected conditions will be distributed to NARS partners for use in breeding programs or for on-farm testing for use by the farmers. The results indicated that there is considerable variation in the reference collection for resistance/susceptibility to *H. armigera*, and selections based on detached leaf assay, and field performance of the lines can be used for developing new breeding lines with resistance to pod borer.

<div align="right">HC Sharma, HD Upadhyaya, N Lalitha and CLL Gowda</div>

Evaluation of bud necrosis and defoliation tolerant germplasm for agronomic traits: During 2008-09 post-rainy season 687 groundnut germplasm accessions were evaluated for resistance to bud necrosis disease and insect defoliation under field condition. Among the defoliating insect pests, *Spodoptera litura* was the most significant one. Based on the previous three seasons performance 20 lines were selected with resistance to BND (< 1),defoliation (< 5%) and high yield (2.25-4.25 t ha^{-1}) compared to standard checks such as M 13, Gangapuri, ICGS 44, ICGS 76 (0.78-1.11 t ha^{-1}). These lines will be further evaluated in sprayed and unsprayed situations in the 2009-10 season.

<div align="right">HD Upadhyaya, GV Ranga Rao and CLL Gowda</div>

Output target 2.1.4 Germplasm accessions regenerated for conservation and distribution (2011)

Output target 2011 2.1.1 Germplasm of staple crops regenerated (2000 accessions) for conservation and distribution

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
A total of 3896 accessions of chickpea (1048), groundnut (423), sorghum (1320), pearl millet (600), and pigeonpea (505) were regenerated for conservation and distribution during 2008-09 post rainy season. 716 accessions, consisting of groundnut (300) and pearl millet (416) were grown during 2009 rainy season and good quantity of seed was obtained from all accessions. Additionally we have grown 3198 critical accessions of sorghum (1695 cultivated and 112 wild), pearl millet (653), chickpea (80), pigeonpea (585) and groundnut (73) for active collection and 8725 accessions of pearl millet (700), chickpea (2971) and groundnut (5054) for duplicate safety back-up at Svalbard Global Seed Vault during 2009-2010 post-rainy season.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Regeneration of germplasm accessions of staple crops with low seed stock/viability (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Critical accessions with low viability and seed stocks of 392 accessions representing sorghum (6), chickpea (90) and groundnut (296) were planted for regeneration in special/controlled environment facilities for seed increase. The growth and establishment in these accessions is excellent for securing sufficient seed for subsequent field regeneration. Similarly, for medium term storage, we planted 3198 accessions representing sorghum (1695 cultivated and 112 wild), pearl millet (653), chickpea (80), pigeonpea (585) and groundnut (73). For duplicate safety back-up at Svalbard Global Seed Vault, Norway, we planted a total of 8725 accessions covering pearl millet (700), chickpea (2971) and groundnut (5054) during the post-rainy season. In pearl millet, 600 accessions planted for 2008 postrainy season were harvested. Good quantity of seed was obtained from all accessions. During 2009 postrainy season, 41 accessions of reference set, 196 accessions of mini core collection and 416 accessions having low seed stock in medium-term store (< ¼ of total quantity) were planted for regeneration. Each accession was planted in 4 rows of 4 m length, spaced at 75 cm, accommodating about 160 plants with a spacing of 10 cm between plants. Bagging of panicles to control the pollination is in progress. Good quantity of seeds was harvested in 100 accessions of *P. violaceum* and *P. mollissimum.* In pigeonpea, 505 pigeonpea accessions, which were planted under insect proof cages in 2008-09 season, for medium-term and long-term conservation were harvested. Sufficient seed quantity was obtained in all regenerated accessions. Our effort to regenerate all accessions of *Cajanus* species was encouraging and we could harvest good quantity of seeds in almost all accessions. Some accessions of *C. albicans*, which flowered in about 450 days, also produced seed in good quantities. During 2009-10, 146 accessions from mini core collection, 14 check cultivars, 9 released cultivars, 89 accessions with poor viability (<75%) and 327 accessions with low seed stock in medium term storage (<1/4 of total quantity) were planted for regeneration under insect proof cages to overcome the problem of out-crossing. Each accession was planted on ridges of 9 m length accommodating 72 plants in 36 hills with a spacing of 25 cm between plants. These accessions will be harvested during Feb-March 2010.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Seed viability and health of new and regenerated germplasm tested and viability of conserved germplasm monitored (Annual)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
NBPGR

Progress/Results:
Seed viability: The seed viability of 10160 accessions was tested during this period. This included 8140 samples of germplasm for medium-term storage (sorghum-3158, pearl millet – 1953, chickpea – 1983, pigeonpea – 340 and groundnut – 706); 851 for long-term storage (sorghum – 437, pigeonpea – 197 and groundnut 217); 487 samples of groundnut for safety back-up and 682 samples of sorghum for active collection for monitoring viability.

During the rainy season, groundnut (1000) accessions were inspected in the field plots during active growth period for their plant health status. All groundnut accessions were found free from quarantine significant pests. Similarly, plant health observations on 3198 accessions planted during post-rainy season representing sorghum (1695 cultivated and 112 wild), pearl millet (653), chickpea (80), pigeonpea (585) and groundnut (73) for medium term storage and a total of 8725 accessions covering pearl millet (700), chickpea (2971) and groundnut (5054) for duplicate safety back-up storage are in progress.

Seed health testing. A total of 2001 germplasm accessions (pearl millet-1049, chickpea-257, pigeonpea-401 and groundnut-294) regenerated from the medium term storage of the genebank were evaluated for their seed health status using the standard blotter method. Four hundred and ninety accessions (pearl millet 273, chickpea 142, pigeonpea 20, and groundnut 55) were free from pathogens. In the remaining accessions we detected 16 fungal species in pearl millet, 12 in chickpea, 13 in pigeon pea and 11 in groundnut. Major seed borne fungi detected were species of *Fusarium, Alternaria, Aspergillus, Curvularia* and *Bipolaris* in pearl millet, *Aspergillus, Alternaria* and *Fusarium* in chickpea and pigeon pea, and *Aspergillus, Rhizoctonia* and *Fusarium* in groundnut. The accessions that were found unfit for storage and distribution varied from 3 to 26% across the crops (pearl millet- 3%, chickpea- 16%, pigeonpea- 26% and groundnut- 14%) as the germination was below 80% and fungal infection from 2 to 100%.

Plant health monitoring during regeneration: During the rainy season, 1,458 germplasm and breeding lines (groundnut -1120, finger millet-148 and foxtail millet-190) consisting of reference set, diverse germplasm, regeneration accessions, international trial entries and elite lines were inspected in the field plots during active growth period for assessing their health status. All groundnut and foxtail millet accessions, except 3 (where downy mildew like symptoms were noticed) were found free from quarantine significant pests. In finger millet 23 accessions were found infected with *Pyricularia grisea*. The infected plants were rogued out and incinerated.

During the post-rainy season, seed multiplication plots of 5 sweet sorghum hybrid parents and 51 A-/B-/R-lines, and 270 chickpea breeding lines were inspected during active growth period for monitoring the plant health status. In sorghum, zonate leaf spot (*Gloeocercospora sorghi*), Cercospora leaf spot (*Cercospora sorghi*) and sheath blight (*Rhizoctonia solani*) were observed in some plants. In chickpea, many plants of an F_2 population showed dry root rot symptoms (*Rhizoctonia bataticola).* All the infected plants were rogued out and incinerated.

Special Project Funding:
NA

<div align="right">RP Thakur, HD Upadhyaya, CLL Gowda and NBPGR</div>

Germplasm samples processed to for medium- and long-term conservation (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Seed harvests of 339 critical accessions of sorghum (6), chickpea (111) and groundnut (220) regenerated in the special facilities were transferred to the Medium term-storage on priority basis. Additionally, seed samples of 4135 accessions regenerated during the rainy and post-rainy seasons were transferred to the medium-term cold rooms following standard protocols. These include sorghum (1320), pearl millet (600), chickpea (1067), pigeonpea (505) and groundnut (643). Processing of sorghum (437), pigeonpea (197) and groundnut (217) accessions for long-term storage, bringing the total base collection to 107,115 accessions covering 90% of entire collection was completed.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Facilities identified for backup safety storage of germplasm collections in collaboration with partners and samples processed for safety backup (Annual)

Achievement of Output Target:
100%

Participating Countries:
India, Italy, Norway

Participating Partners:
GCDT, NBPGR and the Nordic Genetic Resource Center

Progress/Results:
As part of the Agreement between ICRISAT and the Nordic Genetic Resources Center, Norway (earlier known as Nordic Gene Bank), we have deposited the second batch of 23,000 seed samples at the Svalbard Global Seed Vault, Norway following standard protocols of seed health testing and certification by National Bureau of Plant Genetic Resources (NBPGR) in India. An additional 1000 accessions from this set were also sent for germination monitoring in due course of time. The passport and conservation data on these accessions was successfully uploaded to the public data portal at www.nordgen.org/sgsv. With these depositions the total number of duplicate samples of ICRISAT germplasm at the seed vault increased to 43,000 representing sorghum (13,000), pearl millet (8,050), chickpea (6,000), pigeonpea (5,000), groundnut (4,550), finger millet (4,400), foxtail millet (1,000), proso millet (600) and little millet (400). Thus, ICRISAT is fulfilling the role of the great initiative for saving global agricultural biodiversity for future generations.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Output target 2.1.5 Germplasm databases updated for utilization (2009)

Output target 2009 2.1.2 Staple crops germplasm databases updated and uploaded to SINGER database

Achievement of Output Target:
75%
New formats for uploading the databases are to be developed by GPG2 activity coordinators by April 2010

Participating Countries:
Italy

Participating Partners:
SINGER-Bioversity

Progress/Results:
New arrangements are being made for uploading germplasm databases in SINGER. These include development of data dictionary, developing a warehouse based on the dictionary and the data sets consisting of the following:
-    Passport data in MCPD format,
-    Additional GIS fields as per the data dictionary and as far as possible, with checked georeferences
-    Distribution and the cooperator's table
-    Collecting missions.
These are scheduled for completion in the first quarter of 2010. The germplasm databases are being updated accordingly to meet these requirements.

The passport and characterization data of 617 newly acquired pearl millet germplasm accessions and the characterization data on eighty eight accessions of *Pennisetum polystachion* obtained during 2008 was updated and computerized. Similarly, the passport details on new accessions of groundnut (26) and chickpea (127) were added to the database.

The details on germplasm core collections of foxtail millet (155), finger millet (622), and pearl millet (2094) accessions and mini core collections of chickpea (211), pigeonpea (146), sorghum (242) and pearl millet (238) and reference sets of chickpea (300), sorghum (384), groundnut (300), pigeonpea (300) and pearl millet (300) have been added to the ICRISAT website.

We have now developed and installed a software system using Java, SQL Server 2005 for Bar-coding Genebank active and base collections. Following this development we generated permanent adhesive bar coded labels for the active collections of chickpea and groundnut collections and fixed to the containers. This process will be continued for the rest of active collection and base collection also. The new software and hardware also permits printing bar coded field labels for the genebank accessions contributing to better documentation and efficient handling of the collections.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Passport and characterization databases of sorghum and pearl millet germplasm updated (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Characterization data were updated and gaps filled in sorghum for 146 accessions (for days to 50% flowering and plant height); in groundnut for 631 accessions (for 31 characters), and in chickpea for 52 accessions. Passport and characterization data of 617 newly acquired pearl millet germplasm accessions was computerized to update both passport and characterization databases. Characterization data of 88 *P. polystachion* accessions obtained during 2008 was also computerized. Updated passport database for 26 newly acquired groundnut accessions, and 127 chickpea accessions. Information on ICRISAT website on core collections of foxtail millet (155), finger millet (622), and pearl millet (2094), mini core collections of chickpea (211), pigeonpea (146), sorghum (242) and pearl millet (238), and reference sets of chickpea (300), sorghum (384), groundnut (300), pigeonpea (300) and pearl millet (300) was updated. Passport and conservation data of 43000 accessions, deposited at Svalbard Global Seed Vault was uploaded to www. nordgen. Org / sgsv .

A new software program was developed and installed using Java, SQL Server 2005 for Bar-coding of active and base collection. Following this, permanent adhesive bar coded labels were generated for the active collections of chickpea and groundnut and affixed to the containers.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Output target 2010 2.1.6 85% of germplasm characterized and documented for utilization

Germplasm accessions of staple crops characterized for morpho-agronomic traits and documented for utilization (2010)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
During 2009 rainy season, pearl millet germplasm accessions identified as unique in genebank at ICRISAT, Niamey, Niger, were registered and characterized (617 accessions) for 23 morpho-agronomic traits, in an augmented design with systematically arranged checks (IP 3616, IP 17862 and IP 22281), i.e.one check after every 9 test accessions. Each accession was grown in two rows of 4 m length. Characterization data obtained was computerized to update the characterization database. Characterization data of eighty eight *P. polystachion* accessions obtained during 2008 were computerized. Data of *Cajanus scarabaeoides* germplasm (100 accessions) characterized in botanical garden was analysed to assess the diversity in the species.

Special Project Funding:
NA

<div align="right">HD Upadhyaya and CLL Gowda</div>

Output target 2010 2.1.7 Germplasm of staple crops assembled and conserved for utilization at regional genebanks in Africa (Bulawayo, Nairobi and Niamey)

Gaps in sorghum germplasm collection identified, germplasm collected from at least 2 ESA countries and conserved (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Forty-four sorghum accessions collected from the highlands of Tanzania (Karatu, Mbulu, Babati and Hanan'g districts of the Manyara region) were characterized at Kiboko and Kabete during the 2008/09 season and 2009 long rainy season respectively. Quantitative data from Kiboko were subjected to ANOVA and five traits (Days to 50% flowering, Plant height, panicle exertion, panicle length, and panicle width) that showed significant difference ($P=0.05$) were used in PCA and Cluster analyses. High variability was observed in days to 50% flowering (61-243 days) plant height (117.5-430.8cm), panicle exertion (mean 3.5-7.0cm), panicle length (mean 12.3-37.4cm) and panicle width (mean 4.2-11.8cm). Collections from Mbulu were the earliest to flower (mean 77 days) and the late ones were from Hanan'g (mean 119 days). Karatu collections had the longest (mean 27.6cm) and widest (mean 9.8cm) panicles. The accessions were delineated into 5 clusters based on the 5 quantitative traits. Cluster 1 had twelve accessions that were early (mean 98 days), with long panicle exertion (mean 5.8cm) and wide panicles (mean 8.1cm); cluster 2 had long (25.9cm), wide (8.1cm) panicles; cluster 3 had tall accessions (mean 305.8cm); cluster 4 had early accessions (mean 99 days) with narrow panicles and cluster 5 had the late accessions (mean 115 days). All accessions had purple plant color with 42% having semi-compact elliptic panicles, 30% having semi-compact panicles with erect branches, and 15% with compact elliptic panicles. 28% of the accessions had brown seed, 23% were grey, 17% red and 17% white. Grain testa was present in 56% of the accessions with 43% having no testa. The 2009 long rainy season at Kabete had erratic rainfall with high moisture stress during anthesis hence crop performance was poor. However, data on some quantitative and qualitative traits were recorded and are being processed. There may be need to repeat the trial in 2010.

Special Project Funding:
NA

E Manyasa, H Ojulong, M Mgonja, P Sheunda and J Kibuka

Gap analysis for pearl millet collection published (2010)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) genebank in India holds the world's largest collection of 21,594 pearl millet germplasm accessions including 18,447 landraces from 50 countries. West and Central Africa (WCA) region, which is considered as the centre of diversity for pearl millet, is also an important pearl millet germplasm source for resistance to biotic and abiotic stresses. A total of 7372 landraces were assembled from WCA countries. Out of which, 6434 landraces have the georeference data. The geographic origins of these landraces were analyzed using geographic information system tools to identify gaps in the collection. Geographical distribution of existing collections, type of vegetation, land cover and the high probability (>70%) for the occurrence of pearl millet, estimated using the FloraMap software in different countries show that 62 districts in 13 provinces of Nigeria, 50 districts in 16 provinces of Burkina Faso, 9 districts in 6 provinces each of Mali and Mauritania, 8 districts in 8 provinces of Chad and 7 districts in 3 provinces of Ghana as the major geographical gaps in the pearl millet collection at the ICRISAT genebank. In view of this, we suggest that the final areas for exploration in these districts should be decided prior to the launch of the collection missions in consultation with local government officials and extension officers, who have the knowledge of pearl millet cultivation in the districts identified. A journal article published on "Identification of geographical gaps in the pearl millet germplasm from West and Central Africa assembled at ICRISAT genebank" in Plant Genetic Resources: Characterization and Utilization1–7; doi: 10.1017/S147926210999013X".

Special Project Funding:
NA

BIG Haussmann, HD Upadhyaya and CLL Gowda

African accessions of GCP pearl millet reference collection characterized in West Africa (2011)

Achievement of Output Target:
75%
The multi-location characterization trails have been successfully conducted. Data analysis and data preparation for ICRISA data base are currently underway.

Participating Countries:
Nigeria, Mali, Niger

Participating Partners:
LCRI Maiduguri, IER Cinzana, ICRISAT Sadore

Progress/Results:
A multi-location trial consisting of 74 African accessions from the reference collection (those with enough seed) and 7 standards was prepared for evaluation under low-input and fertilized conditions (2 reps each) at LCRI-Maiduguri (Nigeria), IER-Cinzana (Mali), and at ICRISAT-Sadore (Niger). In addition, all 81 regenerated accessions were evaluated with 18 standards at ICRISAT-Sadore for Striga resistance in four replications. The Sadore trials were uniform and should yield good data. Data entry is still underway. The trials in Nigeria

and Mali were visited during the rainy season. Due to religious clashes and subsequent drought, the Maiduguri trial had been planted late on 3rd August 2009. But due to some late rains in October, the LCRI has been able to harvest most of the entries. The Cinzana trial was well managed and close to maturity during the time of the visit on 19th October. High downy mildew pressure and many empty heads (sign of non-adaptation – too early materials) were observed. Otherwise the trial was very uniform, and good data are expected from this site. Data entry is still underway. Partner's data have been received and are currently being analysed. They will be put into the ICRIS data base by May 2010.

Special Project Funding:
Global Crop Diversity Trust

<div align="right">BIG Haussmann</div>

Safety copy of germplasm conserved at Niamey genebank (groundnut, finger millet and pearl millet) (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Germplasm safety copies received from ICRISAT-India were constantly conserved in -20°C deep freezers at Niamey genebank. The safety copies conserved include 5205 pearl millet, 7622 finger millet and 2006 groundnut accessions.

Special Project Funding:
NA

<div align="right">BIG Haussmann</div>

Germination tested for groundnut, sorghum and millet germplasm accessions at Sadore, Niger (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
In 2009, a total of 296 sorghum accessions were tested in Niamey for germination. Critical groundnut accessions were not tested for germination but straight taken to the field for final regeneration, due to low seed quantities.

Special Project Funding:
NA

<div align="right">BIG Haussmann</div>

Critical accessions of groundnut, sorghum and millet regenerated in glasshouses at Sadore, Niger (Annual)

Achievement of Output Target:
100 %

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
In 2009, 13 critical sorghum accessions and 48 critical groundnut accessions were grown in pots in the greenhouse to better protect them and to assure proper regeneration.

Special Project Funding:
NA

<div align="right">BIG Haussmann</div>

Germplasm accessions of groundnut, sorghum and pearl millet regenerated in the field at Sadore, Niger (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
In 2009, 283 sorghum and 1492 groundnut accessions were regenerated by the genebank under field conditions. In addition, the pearl millet improvement program successfully regenerated 81 African accessions from the pearl millet reference collection via manual sibbing. The multiplication experienced problems due to low germination rates; in addition, the accessions received from ICRISAT-India seemed to be inbred which was reflected by low vigor (inbreeding depression compared to own breeding materials) and high segregation for certain traits such as plant height (beyond the phenotypic variation usually observed in West African landraces). The multiplication yielded enough seed for 74 accessions to be evaluated in multi-location trials across three sites and two fertilizer treatments; for 7 accessions, seed was only sufficient for a characterization at Sadore.

Special Project Funding:
NA

BIG Haussmann

Output target 2009 2.1.8 Unrestricted access and movement for staple crops germplasm ensured

Requested germplasm of staple crops distributed to bona fide users for utilization (Annual)

Achievement of Output Target:
100%

Participating Countries:
Twenty four countries – Argentina, Austria, Burkina Faso, Denmark, Ethiopia, France, Germany, India, Israel, Korea, Japan, Mali, Niger, Pakistan, South Africa, Sudan, Sweden, Switzerland, Thailand, Turkey, Uganda, USA, Venezuela and Vietnam

Participating Partners:
NBPGR and NARS from the above-mentioned countries

Progress/Results:
The Patancheru genebank distributed 6020 germplasm samples in 94 consignments for research use in 24 countries following standard germplasm distribution protocols. This included sorghum (2294), pearl millet (1039), chickpea (1235), pigeonpea (500) and groundnut (952). Part of this distribution include 12 sets of mini core collection (sorghum – 5, pearl millet -1, chickpea -3, pigeonpea – 1 and groundnut -2) and two reference sets (one each of chickpea and groundnut) in different countries.

Additionally, 2458 germplasm samples representing sorghum (1266), pearl millet (379), chickpea (137), pigeonpea (481) and groundnut (195) were supplied to scientists within the institute. The supply included one set of mini core and reference set in sorghum, one set of mini core in pearl millet and two sets of mini core in pigeonpea.

The Niamey genebank distributed 332 sorghum accessions and 36 groundnut accessions under SMTA. Further, the pearl millet improvement program distributed, under SMTA 896 pearl millet accessions to various individuals, breeding programs or research institutions.

Special Project Funding:
NA

RP Thakur, HD Upadhyaya, CLL Gowda, NBPGR,
BIG Haussmann and M Mgonja

Requested germplasm of staple crops exported for utilization and new germplasm imported for conservation after seed health evaluation and clearance through NBPGR (Annual)

Achievement of Output Target:
100%

Participating Countries:
Twenty four countries – Argentina, Austria, Burkina Faso, Denmark, Ethiopia, France, Germany, India, Israel, Korea, Japan, Mali, Niger, Pakistan, South Africa, Sudan, Sweden, Switzerland, Thailand, Turkey, Uganda, USA, Venezuela and Vietnam

Participating Partners:
NBPGR NARS from the above-mentioned countries

Progress/Results:
Export: Through NBPGR Hyderabad we facilitated the export of 15,039 seed samples (sorghum-3,538, pearl millet-4,959, chickpea- 4,504, pigeonpea- 445, groundnut-1,405 and small millets-188) to 51 countries under 158 phytosanitary certificates. Additional 286 samples (sorghum-187, groundnut-60 and small millets-39) are under processing. A total of 221 seed samples, about 1.5% of the total, (sorghum-162, pearl millet-11, Chickpea-21, pigeonpea-21, groundnut-5 and small millets-1) were rejected either due to poor germination, and/or association with seedborne fungi (*Bipolaris sacchari*, *Fusarium spp.*, *Botryodiplodia theobromae, Rhizoctonia bataticola, R. solani*), store-grain pests, bacteria of unknown etiology and samples for which FAO designation status not provided by consignors.

PQL directly (without phytosanitary certificate) exported 11 samples of pearl millet to USA and 2,870 plant samples of chickpea to Australia for destructive chemical analysis as per their import permits guidelines.

Import: Seed samples: Through NBPGR we facilitated the import of 754 seed samples (sorghum-145, pearl millet-11, chickpea-188, groundnut-229 and foxtail millet-2 and tomato-179) from 7 countries against 12 import permits. In addition, five import permits, one each for sorghum (230 samples from Mali), pearl millet (251 samples from Niger) and cowpea (40 samples from USA); two for chickpea (100 samples from Syria and 40 samples from USA) were received through NBPGR, New Delhi.

DNA samples: Requests for import permits to import 1180 DNA samples of different crops (potato-378 from Chile, coconut-128 from Sri Lanka, pearl millet-409 from Germany and wheat-265 from Mexico) were processed and permits were issued for Chile and Sri Lanka consignments and others are under process.

Stover samples: Special permission to import 1,264 stover samples (rice -146 from Nigeria, Maize -1000 from Ethiopia and wheat -118 from Mexico) for ILRI and 1,100 decorticated sorghum seed samples from Mali were processed and special permission for all samples were obtained from the Dept of Plant Protection, Quarantine and Storage, Faridabad and released through quarantine procedures to the concerned scientists for nutritional analysis. We also facilitated in releasing of 3,620 imported plant stover samples, cowpea -800 from Ethiopia, lablab- 2700 from Afghanistan and sweet sorghum -120 from Zimbabwe, for which special permission was obtained last year.

Grow-out test for imported samples: During the post-rainy (Nov 2008 -Feb 2009 planted), 776 pearl millet germplasm accessions, 41 sorghum breeding lines and 5 finger millet, 2 foxtail millet and 303 maize accessions were grown in PEQIA. In addition, 498 maize accessions from Mexico (410) and Thailand (88) for SM Sehgal Foundation were also grown in PEQIA. Crops were inspected every fortnight to monitor crop stand and insect disease problems. Some sorghum accessions from Mali and USA developed zonate leaf spot (*Gloeocercospora sorghi*), which was controlled by spraying Mancozeb (0.2%). In pearl millet ISP 596 was found infected with smut (*Moesziomyces penicillariae*); all infected plants were rogued out and incinerated. Healthy plants were harvested and seed were released.

During the rainy season, 309 pigeonpea accessions from Kenya were grown in PEQIA. Of which 81 accessions did not germinate and 188 accessions were infected with Phytophthora blight (PB) (*Phytophthora drechsleri* f. sp. *cajani*). All infected plants were rogued out and incinerated. Of 188, 15 accessions (EC 616531, EC 616493, EC616466EC 616545, EC 616494, EC 616534, EC 616532, EC 616535, EC 616544, EC 616547, EC 616542, EC 616548, EC 616555, EC 616455 and EC 616471) were found highly susceptible. This is an important information for breeders and pathologists.

In PQ greenhouse, 42 Chickpea accessions (USA-33 and Israel- 9) were grown for disease monitoring and seed increase. These samples were found infected with bacteria (unknown etiology) during the blotter test. However, these plants were found free from any bacterial infection in the grow-out test. Four accessions from Niger were also grown in greenhouse and found healthy.

During the post-rainy season (2009-10), 270 chickpea accessions from USA and Australia, 185 groundnut accessions from USA, and 19 sorghum accessions from France were planted in PEQIA. These have been assessed for exotic pests and diseases.

Special Project Funding:
NA

RP Thakur, HD Upadhyaya, CLL Gowda and NBPGR

Output 2.2: Germplasm of six small millets assembled and conserved; germplasm characterized/ evaluated and documented for utilization and knowledge shared with partners

Summary: In addition to the mandate crops, ICRISAT genebank also works on the collection and conservation of small millets. Assembly and conservation of 558 accessions of finger millet identified and regenerated during 2008 in Kenya and Uganda is progressing at the regional genebanks in Africa and at Patancheru. A comparison of germplasm databases of ICRISAT with that of NIAS, Japan identified 294 finger millet, 1286 foxtail millet, 395 kodo millet and 296 proso millet lines as unique for Patancheru location. Like wise, 322 finger millet accessions from the Nairobi regional genebank and 359 accessions from the All India Coordinated Small Millets Improvement Program were identified as unique and not available in our collection.

Analysis of databases of small millets for identification of priority geographical area for collection showed that Bangladesh, China, India, Japan and Korea in Asia; Chad in Central Africa; Rwanda, Tanzania and Zaire in Eastern Africa; Angola and Mozambique in Southern Africa; and Cote d' Ivoire in West Africa are underrepresented in our small millet collection. In small millets, a total of 1069 germplasm accessions, finger millet (820), foxtail millet (179), little millet ((33) proso millet (12), barnyard millet (15) and kodo millet (10) were regenerated during 2008 rainy season for medium-term storage and to meet immediate user needs. A total of 456 accessions of six small millets were characterized for morpho-agronomic traits during 2009. A wide range of diversity was observed in these accessions. Additionally 52 accessions were characterized for diversity assessment, 20 accessions for to fill the gaps in databases. We also regenerated and processed the seed of 785 accessions of finger millet, 162 accessions of foxtail millet, 23 accessions of barnyard millet, 29 accessions of little millet, 7 accessions of proso millet and 7 accessions of kodo millet for medium-term conservation during 2008 rainy season

During the rainy season 2009, a total of 1019 critical accessions covering finger millet (165) and foxtail millet (219) for medium-term storage and finger millet (360) and foxtail millet (275) for safety back up at Svalbard Global Seed Vault were grown. As part of the Agreement between ICRISAT and the Nordic Genetic Resources Center, Norway a second batch of 23,000 seed samples were deposited at the Svalbard Global Seed Vault, Norway following standard protocols. This included proso millet (600) and little millet (400) accessions. With these depositions the total number of small millets duplicates samples of ICRISAT germplasm at the seed vault increased to 6,400 representing finger millet (4,400), foxtail millet (1,000), proso millet (600) and little millet (400). The passport and conservation data on these accessions was successfully uploaded to the public data portal at www.nordgen.org/sgsv.

A total of 679 germplasm samples for research use in four countries were sent following standard germplasm distribution protocols. This included finger millet (129), foxtail millet (444), proso millet (34), little millet (5), kodo millet (5) and barnyard millet (62). Additionally, 1213 germplasm samples representing finger millet (891), foxtail millet (318) and one each of proso millet, little millet, kodo millet and barnyard millet were supplied to scientists within the institute. A total of 188 germplasm of small millets were exported to Denmark (30) and France (158). These consisted of five samples each of finger, proso, foxtail, little, kodo and barnyard millets to Denmark and 158 of foxtail millet to France.

Output target 2009 2.2.3 Priority areas identified for foxtail millet, little millet, kodo millet, proso millet and barnyard millet for collection/assembly in collaboration with NARS

Achievement of Output Target:
100%

Participating Countries:
India, Italy, Japan, Kenya and Uganda

Participating Partners:
GCDT, and NARS from India, Japan, Kenya and Uganda

Progress/Results:
ICRISAT is an active partner collaborating with the Global Crop Diversity Trust (GCDT) in developing the global conservation strategies for the germplasm of its mandate crops and small millets. As a follow-up to the earlier meetings, the Trust has developed several regeneration projects around the world (five crops and 49 national collections in 29 countries) for conserving unique global collections and 17,154 unique accessions including finger millet (3159) were identified. About 558 accessions of finger millet identified and regenerated during 2008 in Kenya and Uganda are being considered for assembly and conservation at the regional genebanks in Africa and Patancheru.

The germplasm passport databases of ICRISAT was compared with that of NIAS, Japan and 294 finger millet, 1286 foxtail millet, 395 kodo millet and 296 proso millet were identified as unique for Patancheru location . Like wise the Nairobi regional genebank database contributed 322 finger millet accessions. Efforts will be made to assemble these unique collections during 2010. Similarly, the All India Coordinated Small Millets Improvement Program (AICSMIP) database of finger millet was compared with ICRISAT germplasm database which resulted in identifying 359 accessions as unique and not available in our collection.

Gap analysis was performed on the passport databases of small millets for identification of priority geographical area for small millet collection. Bangladesh, China, India, Japan and Korea in Asia, Chad in Central Africa, Rwanda, Tanzania and Zaire in Eastern Africa, Angola and Mozambique in Southern Africa, and Cote d' Ivoire in West Africa are underrepresented in our small millet collection

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Output target 2010 2.2.2 Germplasm of six small millets conserved with 50% of germplasm characterized/evaluated for desirable traits and documented for utilization

Germplasm of six small millets conserved and characterized/evaluated for desirable traits and documented for utilization (2010)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
In small millets, 1069 germplasm accessions, regenerated during 2008 rainy season were processed for medium-term storage as active collection and as working collection to meet immediate user needs. These accessions included, finger millet (820), foxtail millet (179), little millet (33) proso millet (12), barnyard millet (15) and kodo millet (10).

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Output 2009 2.2.1 Gaps in finger millet collection identified and potentially filled in at least two countries in ESA

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Finger millet collection gaps were identified in Kenya, Uganda and Tanzania. Database for sorghum collection including passport data was acquired from ICRISAT India. The NARS partners were contacted to verify whether there are additional collections that were done and information has not been made available to ICRISAT. Tanzanian and Kenyan curators provided additional datasets of 275 and 1908 lines, respectively. The Uganda database had 127 out of 820 accessions, not geo-referenced. For those accessions that had village names, GIS experts were consulted and they determined village geo-references. The other limitation for this data base was that most of the geo-references provided were for the multiplication sites and did not reflect the site where the materials were collected. The GIS unit at ICRAF was consulted and mapped all the available collections. Partners in the NARS, who have local knowledge of finger millet producing areas,

were consulted to assist in identifying collection gaps in their respective countries. Evidence of collection gaps in Kenya, Uganda and Tanzania provide opportunity for conducting targeted collection to fill gaps and this will help enrich the finger millet crop diversity and enhance its crop improvement. The remaining tasks are to conduct collection in the targeted areas and this will be done under the HOPE project milestones.

Special Project Funding:
NA

<div align="right">M Mgonja, E Manyasa, H Ojulong, P Sheunda and J Kibuka</div>

Germplasm of foxtail millet, little millet, kodo millet, proso millet and barnyard millet characterized (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
A total of 456 accessions of six small millets were characterized for morpho-agronomic traits during 2009. A wide range of diversity was observed in these accessions. Additionally 52 accessions were characterized for diversity assessment, 20 accessions to fill gaps in databases. We also regenerated and processed the seed of 785 accessions of finger millet, 162 accessions of foxtail millet, 23 accessions of barnyard millet, 29 accessions of little millet, 7 accessions of proso millet and 7 accessions of kodo millet for medium-term conservation during 2008 rainy season.

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Passport, characterization and evaluation data of small millets germplasm documented

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Characterized and documented 20 accessions and filled the gaps in small millet database of finger millet (11 accessions), foxtail millet (5 accessions), little millet (one accession) and kodo millet (3 accessions) for important morpho-agronomic characters.

We documented the passport characterization information of 44 newly acquired foxtail millet germplasm accessions from Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. These 44 accessions were classified into races and subraces, race moharia (subrace: glabra 2 accessions), race maxima (subrace: spongiosa 2 accessions) and race indica (subrace: nana 36, and glabra 4).

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Output target 2010 2.2.3 Databases of small millets germplasm updated for utilization

Output 2009 2.2.2 Germplasm databases of small millets updated

Achievement of Output Target:
100%

Participating Countries:
Italy

Participating Partners:
SINGER-Bioversity

Progress/Results:
New arrangements are being made for uploading germplasm databases in SINGER. These include development of data dictionary, developing the warehouse based on the dictionary and the data sets consisting of
- Passport data in MCPD format,
- Additional GIS fields as per the data dictionary and with, as far as possible, checked georeferences
- Distribution and the cooperators' table
- Collecting missions.

These are scheduled for completion in the first quarter of 2010. The small millet databases are being updated to meet the above requirements.The details on germplasm core collections of foxtail millet (155) and finger millet (622) have been added to the ICRISAT website.

We have now developed and installed a software system using Java, SQL Server 2005 for Bar-coding Genebank's active and base collections. Following this development we generated permanent adhesive bar coded labels for the active collections and base collections of six small millets. The new software and hardware also permits printing bar coded field labels for the genebank accessions contributing to better documentation and efficient handling of the collections.

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Output target 2009 2.2.4 Germplasm accessions regenerated for conservation and distribution

Germplasm accessions of small millets with limited seed stock/viability regenerated and seed samples processed for medium- and long-term conservation (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
The regenerated germplasm totaling 1069 accessions from 2008 rainy season was processed for medium-term storage as active collection and as working collection to meet immediate user needs. The total included finger millet (820), foxtail millet (179), little millet (33) proso millet (12), barnyard millet (15) and kodo millet (10), accessions.

We planted, 1019 critical accessions covering finger millet (165) and foxtail millet (219) for medium-term storage and finger millet (360) and foxtail millet (275) for safety back up at Svalbard Global Seed Vault during the rainy season 2009. Sufficient seed stocks of these accessions were obtained.

Special Project Funding:
NA

<div align="right">CLL Gowda and HD Upadhyaya</div>

Seed viability and health of new and regenerated small millets germplasm tested and viability of conserved germplasm monitored (Annual)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
NBPGR

Progress/Results:
The seed viability of 991 accessions of small millets was tested during this period. This included 829 samples of finger millet and 162 samples of foxtail millet germplasm for medium-term storage.

Plant health during regeneration: During the rainy season, a total of 338 germplasm accessions (finger millet 148 and foxtail millet 190) were inspected in the field plots during active growth period for their plant health status. All accessions of foxtail millet except three where downy mildew like symptoms were noticed were found free from quarantine significant pests. In finger millet 23 accessions were found infected with *Pyricularia grisea* Sacc. (Perfect state: *Magnaporth grisea* Barr.). The infected plants were rogued out and incinerated.

Special Project Funding:
NA

<div align="right">CLL Gowda, RP Thakur and HD Upadhyaya</div>

Small millets germplasm processed for safety back up (Annual)

Achievement of Output Target:
100%

Participating Countries:
India, Italy, Norway

Participating Partners:
GCDT, NBPGR and the Nordic Genetic Resource Center

Progress/Results:
As part of the Agreement between ICRISAT and the Nordic Genetic Resources Center, Norway (earlier known as Nordic Gene Bank), we have deposited the second batch of 23,000 seed samples at the Svalbard Global Seed Vault, Norway following standard protocols of seed health testing and certification by National Bureau of Plant Genetic Resources (NBPGR) in India. This included proso millet (600) and little millet (400) accessions. The passport and conservation data on these accessions was successfully uploaded to the public data portal at www.nordgen.org/sgsv. With these depositions the total number of small millets duplicates samples of ICRISAT germplasm at the seed vault increased to 6,400 representing finger millet (4,400), foxtail millet (1,000), proso millet (600) and little millet (400).

Special Project Funding:
NA

CLL Gowda, HD Upadhyaya, RP Thakur, B Haussmann and NBPGR

Output target 2011 2.2.5 Germplasm of small millets supplied on request

Requested germplasm of small millets distributed to bonafide users for utilization (Annual)

Achievement of Output Target:
100%

Participating Countries:
India, China, Denmark and France

Participating Partners:
NBPGR and NARS from the above-mentioned countries

Progress/Results:
A total of 679 germplasm samples distributed following standard germplasm distribution protocols, in 20 consignments for research use in four countries. This included finger millet(129), foxtail millet(444), proso millet(34), little millet(5), kodo millet(5) and barnyard millet (62).
Additionally, 1213 germplasm samples representing finger millet (891), foxtail millet (318) and one each of proso millet, little millet, kodo millet and barnyard millet were supplied to scientists within the institute. The supply included one set of core and 4 sets of mini core collection in finger millet and two sets of core collection in foxtail millet.

Special Project Funding:
NA

RP Thakur, HD Upadhyaya, CLL Gowda and NBPGR

Requested germplasm of small millets exported for utilization and new germplasm imported for conservation after seed health evaluation and clearance through NBPGR (Annual)

Achievement of Output Target:
100%

Participating Countries:
India, China, Denmark and France

Participating Partners:
NBPGR and NARS from the above-mentioned countries

Progress/Results:
A total of 188 germplasm of small millets were exported to Denmark (30) and France (158) under 7 phytosanitary certificates. These consisted of five samples each of finger millet, proso millet, foxtail millet, little millet, kodo millet and barnyard millet to Denmark (under 6 phytosanitary certificates) and 158 foxtail millet to France (under 1 phytosanitary certificate). Two foxtail millet samples were imported from Italy. These samples could not germinate when planted in PEQIA for evaluation of exotic seed borne pathogens.

Special Project Funding:
NA

RP Thakur, HD Upadhyaya, CLL Gowda and NBPGR

Output 2.3: Core, and mini-core collections and trait specific germplasm identified and evaluated and composite collections and reference sets developed and genotyped for utilization and new knowledge shared with partners

Summary: With the objective of accelerating the utilization of germplasm in crop improvement, composite collections of foxtail millet (500 accessions) have been molecularly profiled using about 19 SSR (Simple Sequence Repeats) markers. A reference set of 200 genetically most diverse accessions was established. Likewise composite collections were molecularly profiled for chickpea (3000 accessions, 50 SSRs), groundnut (1000 accessions, 21 SSRs), pigeonpea (1000 accessions, 20 SSRs), finger millet (1000 accessions, 20 SSRs), pearl millet (1000 accessions, 19 SSRs) and sorghum (3385 accessions, 43 SSRs) to constitute reference sets of about 300 accessions each.

New trait specific donors (germplasm) for most economic characters have been identified in chickpea, pigeonpea, groundnut, pearl millet, sorghum and minor millets. Drought and salinity tolerance sources as well as donors for stay-green, sweet stalk -high grain-high fodder yield, have also been identified. Sources of Helicoverpa pod borer resistance in chickpea and pigeonpea; grain mold, leaf blight, rust, anthracnose and downy mildew resistance in sorghum; downy mildew in pearl millet; neck-finger-leaf blast in finger millet; neck blast in foxtail millet have been identified.

Reference sets of Sorghum and groundnut were evaluated under water stress conditions and genotypes with minimum water use for near normal yields were identified along with optimal root characters.

Output target 2010 2.3.1 Core and mini core collections of germplasm established for utilization

Diversity of pearl millet core collection studied (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
The evaluation and characterization of germplasm collections provide important information to plant breeders which can be used to enhance crop improvement activities, and to the genebank managers for effective germplasm management. Pearl millet core was evaluated for 10 qualitative and eight quantitative characters in an augmented design during rainy season, 2007 at ICRISAT, Patancheru, India and using this data, the phenotypic diversity in the pearl millet core collection comprising of 2094 accessions was described. Accessions were stratified according to maturity groups and geographical regions. There was considerable variability for both qualitative and quantitative characters in the core as depicted by mean, range, variance and diversity index. Within accession variance was greater than between accession variance for number of total and productive tillers, panicle exertion and panicle thickness. Almost all the phenotypic classes of qualitative traits were represented in the core collection. Maturity groups were significantly different for means of all the quantitative traits except panicle length, and for variances of days to 50% flowering, plant height, number of productive tillers and 1000-seed weight. Geographical regions differed significantly for means and variances of all the quantitative traits. South Asia followed by West Africa exhibited maximum range of variation for different traits. The Shannon-Weaver diversity index was variable in different maturity groups and regions for different traits. Among qualitative traits, endosperm texture and among quantitative traits, panicle thickness showed the highest pooled diversity index. Majority of the phenotypic correlations were significant in the core, and showed a uniform pattern for most of the quantitative traits in all the maturity groups and geographical regions. Principal component analysis suggested that number of total tillers, panicle thickness and length are important traits for characterization of pearl millet germplasm. Hierarchical clustering performed on the first three principal component scores resulted in four clusters. The results from the study have been discussed in the context of enhancing the use of germplasm in breeding programs, and ultimately leading to development of a functional core rather than a theoretical core collection. A journal article is under preparation.

Special Project Funding:
NA

HD Upadhyaya, DV Yadav and CLL Gowda

Mini core collection of pearl millet germplasm established for utilization (2010)

Achievement of Output Target:
75%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pearl millet exhibits enormous genetic diversity in the entire global collection comprising of 21,594 accessions from 51 countries. The pearl millet core collection with 2094 accessions from 46 countries is still very large for effective utilization in crop improvement program. Hence, a mini core collection of pearl millet comprising of 238 accessions was constituted by evaluating the core collection for 18 morpho-agronomic traits in augmented design in the rainy season of 2007. The hierarchical cluster analysis of data using phenotypic distance matrix resulted in 136 clusters. A proportional sampling strategy was used and, about 10% or a minimum of one accession from each cluster was selected to form the mini core collection. Comparison of the mini core and core collection was done using various statistical parameters such as homogeneity of distribution for geographic regions and countries, frequency distribution of phenotypic classes in qualitative traits, means, variances, phenotypic diversity indices, and phenotypic correlations. Zero values of MD% and VD% and high overall values of CR% (91.2%) and VR% (107.1%) indicated that the variance and distribution ranges are well represented in the mini core and that almost the entire genetic variation present in the core collection is captured by the mini core collection. The core and mini core exhibited similar pattern for between and within accession variance of different traits. Between accessions variance was more than within accession variance for days to flowering, plant height and panicle length. Meaningful correlation observed between number of total and productive tillers was conserved in the core and mini core. The mini core should be considered as a good representation of genetic diversity available in the core and entire collection of pearl millet at ICRISAT. With its greatly reduced size, the mini core can be evaluated for traits of agronomic importance, biotic and abiotic stresses, and mapping with molecular markers to identify trait-specific germplasm for discovery of new genes and in genetic studies. A journal article is under preparation.

Special Project Funding:
NA

HD Upadhyaya, DV Yadav and CLL Gowda

Mini core subset of finger millet established (2009)

Achievement of Output Target:

100%

Progress/Results:
Finger millet [*Eleusine coracana* (L.) Gaertn.], among small millets, is the most important food crop in some parts of Asia and Africa. The grains are a rich source of protein, fiber, minerals and vitamins. A core collection of 622 accessions was developed. Finger millet mini core collection was developed using multilocational evaluation data of the core collection. Six hundred and twenty-two accessions together with six controls (four common and two location-specific) were evaluated for 20 morphological descriptors at five agro-ecologically diverse locations in India during the 2008 rainy season. The experiment was conducted in alpha design with two replications at Patancheru and in augmented design with one of the six controls repeated after every nine-test entry at other locations. The hierarchical cluster analysis of data using phenotypic distances resulted in 40 clusters. From each cluster, ~10% or a minimum of one accession was selected to form a mini core, which comprised of 80 accessions. The comparison of means, variances, frequency distribution, Shannon and Weaver diversity index (H`) and phenotypic correlations revealed that the mini core captured the entire diversity of the core collection. This mini core collection is an ideal pool of diverse germplasm for identifying new sources of variation and enhancing the genetic potential of finger millet. A journal article is accepted for publication in Crop Science.

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Output target 2.3.2 Composite collections of germplasm established for utilization (2009)

Germplasm composite collections for finger millet (1000 accessions) and foxtail millet (500 accessions) established (2009)

Achievement of Output Target:
100%

Progress/Results:
Finger Millet composite collection: Finger millet [*Eleusine coracana (L.) Gaertn]*, also known as African millet or ragi is an annual plant widely grown as cereal in the arid areas of Africa and Asia. With the objective of increasing the utilization of finger millet germplasm in crop improvement, a composite collection consisting of 1000 accessions was developed (Table 7). The composite collection has been molecularly profiled using 20 SSR (Simple Sequence Repeats) markers. Allelic data on 959 accessions and 20 markers based on quality index was used for further analysis. A total of 231 (121 common and 110 rare) alleles were detected in the composite collection (Table 8). Gene diversity varied from 0.200 to 0.850. Group specific unique alleles observed among the races, were 37 in Vulgaris, 5 in Plana, 4 in Africana and 2 in Compacta, and region wise, 29 in East Africa, 12 in South Asia, 11 in Southern Africa, and one each in Central Africa and Europe. The average multiple alleles were highest (13.6%) in race Spontanea wild types and ranged 1.7 to 9.5% in other races. A reference set consisting of 300 genetically most diverse accessions was established (Figure 1). The reference set had 206 (89.2%) of the 231 alleles detected in the composite collection, and showed high gene diversity (0.307 to 0.852) (Tables 7-8)

Table 7. Number of accessions from different countries/regions included in the finger millet composite collection.

Region/ country of Origin	No of Accessions	Region/ country of Origin	No of Accessions
Eastern Africa	**362**	**Central Africa**	**3**
Tanzania	11	Cameroon	3
Uganda	205	**South Asia**	**328**
Ethiopia	4	India	249
Kenya	137	Maldives	2
Burundi	5	Nepal	74
Southern Africa	**261**	Pakistan	1
Mozambique	1	Sri Lanka	2
Zambia	38	**America**	**5**
Zimbabwe	135	USA	5
Malawi	87	**Europe**	**7**
Western Africa	**7**	United Kingdom	3
Senegal	1	Italy	3
Nigeria	6	Germany	1

Region/ country of Origin	No of Accessions	Region/ country of Origin	No of Accessions
		Unknown	**27**
		Total	**1000**

Table 8. Allelic composition, polymorphic information content (PIC), gene diversity, and percentage of multiple alleles in composite collection (20 SSR loci data on 959 accessions) of finger millet.

| Marker	Allelic richness	Allele size (bp)	Rare allele (1%)	Common allele	PIC value	Gene diversity	Multiple alleles (%)
UGEP11	7	145-165	4	3	0.316	0.36	1
UGEP56	8	160-168	5	3	0.313	0.35	13
UGEP8	10	285-305	5	5	0.452	0.55	14
UGEP15	11	165-185	2	9	0.753	0.78	10
UGEP3	10	195-205	5	5	0.558	0.62	12
UGEP5	21	205-215	13	8	0.636	0.67	19
UGEP81	10	225-230	5	5	0.388	0.42	4
UGEP104	8	189-201	4	4	0.364	0.39	2
UGEP107	9	225-240	5	4	0.196	0.2	4
UGEP31	10	235-245	3	7	0.523	0.59	10
UGEP18	12	310-340	4	8	0.669	0.72	17
UGEP65	10	195-205	5	5	0.367	0.42	0
UGEP68	8	225-240	3	5	0.543	0.59	2
UGEP90	8	225-235	3	5	0.539	0.59	2
UGEP1	8	180-186	3	5	0.559	0.63	2
UGEP10	16	295-405	9	7	0.57	0.6	12
UGEP102	16	180-190	9	7	0.63	0.67	17
UGEP12	20	210-240	9	11	0.834	0.85	9
UGEP26	12	215-230	6	6	0.497	0.52	16
UGEP77	17	240-275	8	9	0.644	0.68	9
Mean	11.6	-	5.5	6.1	0.518	0.56	9
Min	7	-	2	3	0.196	0.2	0
Max	21	-	13	11	0.834	0.85	19
Total	231	-	110	121	-	-	-
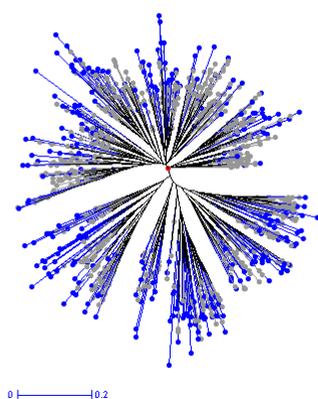
Figure 1. Unweighted neighbour-joining tree based on the simple matching dissimilarity matrix of 20 SSR markers across the composite collection (Grey colour) with the reference set (300 accessions) in blue colour

Foxtail millet composite collection: Foxtail millet (*Setaria italica (L). P. Beauv.*), once a major food crop in early agriculture of Eurasia, is now a minor cereal and reduced to a relic crop in many parts of the world. Using passport and characterization data on entire ICRISAT

foxtail millet germplasm collection, a composite collection (500 accessions) was developed (Table 9). The composite collection was genotyped using 19 SSRs in high throughput assay to detect genetic structure and diversity and from it extract genetically most diverse accessions to construct a reference set. Allelic data of 19 SSR loci on 452 accessions detected 362 alleles, of which, 196 were common and 166 rare alleles (Table 10). Gene diversity varied from 0.012 to 0.670. A number of group-specific unique alleles were detected: 40 in Indica, 21 in Moharia, 10 in Pumila, and eight in Maxima among races, while among regions, 57 in South Asia, 17 in West Asia, 14 in East Asia, and three in Africa. The shared common alleles were 28 between Moharia and Indica, 16 between Maxima and Indica, nine between Maxima and Moharia, four between Moharia and Pumila, three each between Italica and Indica and Pumila and Indica. Region-wise shared common alleles were 43 between East Asia and South Asia, 24 between South Asia and West Asia, 4 between Africa and South Asia, three each between East Asia and West Asia and Africa and West Asia, and two between Africa and East Asia. A reference set of 200 genetically most diverse accessions was established, capturing 316 (87.3%) of the 362 alleles detected in the composite collection (Figure 2). The utility of this reference set in foxtail millet genomics and breeding is being further investigated

Table 9. Number of accessions from different countries included in the foxtail millet composite collection.

Country of origin	No of accessions	Country of origin	No of accessions
Africa	**13**	Spain	1
Cameroon	8	Switzerland	1
Ethiopia	1	United Kingdom	1
Kenya	1	**South Asia**	**238**
Malawi	1	India	211
South Africa	2	Pakistan	10
America	**9**	Sri Lanka	11
Mexico	1	Nepal	3
USA	8	Myanmar	3
East Asia	**112**	**West Asia**	**122**
Korea	9	Afghanistan	8
Taiwan	17	Iran	2
China	37	Lebanon	17
Russia & CIS	49	Syria	84
Europe	**5**	Turkey	11
Hungary	2	**Unknown**	**1**
		Total	**500**

Table 10. Allelic composition, polymorphic information content (PIC), gene diversity, and heterozygosity in composite collection (19 SSR loci data on 452 accessions) of foxtail millet.

| Marker	Range	Allele no	Common alleles	Rare alleles	Hetero-zygosity	PIC	Gene diversity
P2	108- 130	10	7	3	0.183	0.582	0.624
P13	150- 194	14	11	3	0.086	0.832	0.848
P5	277- 310	10	8	2	0.135	0.544	0.564
UGEP8	292- 300	5	4	0	0.012	0.114	0.115
UGEP53	176- 284	35	18	17	0.407	0.907	0.913
UGEP81	110- 236	30	9	21	0.122	0.712	0.745
UGEP102	176- 206	11	7	4	0.155	0.603	0.639
UGEP3	166- 208	22	15	7	0.311	0.754	0.765
UGEP15	150- 238	31	23	8	0.239	0.919	0.923
UGEP56	120- 174	24	9	15	0.219	0.521	0.542
UGEP90	163- 269	28	13	15	0.086	0.635	0.65
ICMMO2C24	316- 398	30	7	24	0.239	0.684	0.724
ICMMO2D15B	132- 166	16	10	6	0.157	0.296	0.306
ICMMO2D07	226- 256	11	9	2	0.635	0.791	0.814
UGEP11	146- 176	13	7	6	0.115	0.257	0.264
UGEP12	210- 248	19	8	11	0.291	0.849	0.864
UGEP77	227- 291	33	20	13	0.67	0.853	0.863
UGEP26	207- 240	12	8	4	0.125	0.334	0.34
ICMMO2C05	184- 208	8	3	5	0.012	0.145	0.149
Total	-	362	196	166	-	-	-
Mean	-	19.1	10.3	8.7	0.221	0.596	0.6137
Min	-	5	3	0	0.012	0.114	0.115
Max	-	35	23	24	0.67	0.919	0.923
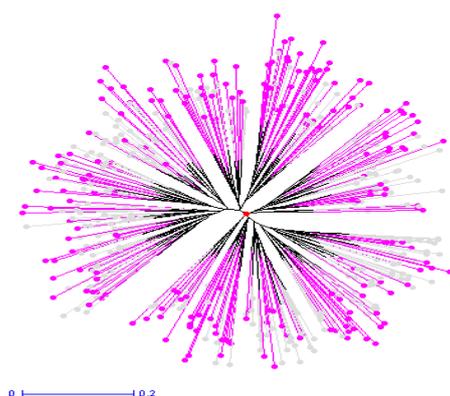
Figure 2. Unweighted neighbour-joining tree based on the simple matching dissimilarity matrix of 19 SSR markers across the 452 accessions of foxtail millet composite collection (Grey colour) with proposed reference set (200 accessions) in pink colour.

HD Upadhyaya, A Bharthi, CT Hash, CLL Gowda, RK Varshney and A Rathore

Output target 2010 2.3.3 New reference sets of chickpea, groundnut, pigeonpea and sorghum germplasm (300 accessions each) established and evaluated for utilization

Genotype composite collections for studying diversity and population structure and developing reference sets of staple crops

Achievement of Output Target:
100%

Participating Countries:
India, Syria

Participating Partners:
ICRISAT, ICARDA, CIRAD, EMBRAPA, GCP

Progress/Results:

Chickpea: Genotyped composite collections of chickpea (3000 accessions) with 50 SSR markers. After data validation 48 SSR loci data on 2915 accessions were analyzed using PowerMarker V3.0 and DARwin 5.0 version. This composite collection showed rich allelic diversity (1683 alleles, 35 alleles per locus, 748 most common alleles and 935 rare alleles at 1%), group-specific unique alleles, and common alleles sharing between the species and geographical groups. Unique alleles are those detected in a group of accessions but absent in other groups. Group-specific unique alleles were 104 in Kabuli, 297 in desi, and 69 in wild *Cicer*; 114 each in Mediterranean and West Asia (WA), 117 in South and South East Asia (SSEA), and 10 in African region accessions. Desi and kabuli shared 436 alleles while wild *Cicer* with desi and kabuli, respectively, shared 17 and 16 alleles. The accessions from SSEA and WA shared 74 alleles while those from Mediterranean shared with WA and SSEA, 38 and 33 alleles respectively. Desi types possessed higher proportion of rare alleles (53%) than kabulis (46%), while wild *Cicer* accessions were devoid of rare alleles. A reference set consisting of 300 genetically most diverse accessions have been formed. This reference set captured 1315 (78%) of the 1683 composite collection alleles, representing diversity from the entire spectrum of composite collection. A journal article was published in BMC Biology.

Groundnut: Genotyped composite collections of groundnut (1000 accessions) with 21 SSR markers. After data validation 21 SSR loci data, on 852 accessions were analyzed. This composite collection showed rich allelic diversity (490 alleles, 23.3 alleles per locus, 246 common alleles and 244 rare alleles at 1%), group-specific unique alleles, and common alleles shared between subspecies and geographical groups. Gene diversity ranged from 0.559 to 0.926, with an average of 0.819. Unique alleles are those detected in a group of accessions but absent in other groups. Group-specific unique alleles were 101 in wild *Arachis*, 50 in subsp. *fastigiata*, and only 11 in subsp. *hypogaea*. Accessions from Americas revealed highest number of unique alleles (109) while Africa and Asia, respectively, had only six and nine unique alleles. The two subsp. *hypogaea* and *fastigiata* shared 70 alleles. The wild *Arachis* in contrast shared only 15 alleles with *hypogaea* and 32 alleles with *fastigiata*. A tree-diagram using DARwin 5.0 separated majority of the *hypogaea* from *fastigiata* accessions while wild *Arachis* accessions clustered with *hypogaea*. A reference set consisting of 300 genetically most diverse accessions have been formed. This reference set captured 466 (95%) of the 490 composite collection alleles, representing diversity from the entire spectrum of composite collection.

Pigeonpea: Genotyped composite collections of pigeonpea (1000 accessions) with 20 SSR markers. After data validation 20 SSR loci data on 952 accessions were analyzed. This composite collection showed rich allelic diversity (197 alleles, 10 alleles per locus, 82 most common alleles and 115 rare alleles at 1%), group-specific unique alleles, and common alleles sharing between the species and geographical groups. Unique alleles are those detected in a group of accessions but absent in other groups. Group-specific unique alleles were 60 in wild types and 64 in cultivated types. Accessions from Asia had 48 unique alleles while those from Africa had only two unique alleles. Non-determinate type (NDT) cultivated pigeonpea accessions were represented by 37 unique alleles while determinate types (DT) only one allele. Wild and cultivated types shared 73 alleles, DT and NDT 10 alleles, DT and wild types 4 alleles, and NDT and wild types 20 alleles. A tree diagram using DARwin 5.0 revealed wild types as a group genetically more diverse than cultivated types, while NDT were more diverse than DT. A reference set consisting of 300 genetically most diverse accessions have been formed. This reference set captured 187 (95%) of the 197 composite collection alleles, representing diversity from the entire spectrum of composite collection.

Pearl Millet: Genotyped composite collections of pearl millet (1000 accessions) with 19 SSR loci spread across seven linkage groups of pearl millet to study genetic diversity and population structure and from it select a reference set of 300 most diverse accessions. The composite collection accessions were highly heterogeneous and up to 8 alleles were detected per locus. A total of 230 alleles were detected, of which, 102 were rare alleles (1%). Only seven alleles were unique in wild species whereas 30 in landraces. The clustering pattern indicated that the accessions were largely grouped by geographically but not by biological status. The released cultivars and breeding materials were scattered across different clusters. A reference set of 300 accessions was chosen based on Euclidean distance matrix derived from allele frequency values. The reference set has captured 94.8 per cent of the composite collection alleles (230). This reference set will be profiled with additional markers and extensively phenotyped for traits of economic importance to identify accessions with beneficial traits for utilization in pearl millet breeding and genomics. A journal article is under preparation

Sorghum: Genotyped composite collections of sorghum (3385accessions) with 43 SSR markers. After data validation 41SSR loci data across 10 chromosome pairs of *Sorghum bicolor* on 3365accessions was analyzed. Sorghum landrace population structure is characterized by racial subgroups (five basic races and ten intermediate races) within geographic origin. Further, race bicolor shows little evidence of population structure, as expected for the original domesticate. Race kafir (largely from Southern Africa) is distinct. Accessions of the durra, caudatum and guinea races each form distinct geographic subgroups. The guinea race margaritiferum group forms its own cluster (along with the majority of wild and weedy accessions), suggesting its independent domestication. Intermediate races behaved similarly to the five basic races.

Special Project Funding:
GCP Projects

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S Senthivel, DA Hoisington and CLL Gowda</div>

Output target 2009 2.3.4 Core, mini core, and or reference sets of germplasm evaluated for utilization in Asia (2009)

Reference set of chickpea phenotyped for agronomic traits (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Evaluated chickpea reference set and five control cultivars (desi -Annigeri, G130 and ICCV10; kabuli - L550 and KAK 2) in alpha design under normal and high temperature environments (sown in the first week of February to expose the crop to high temperatures in March/April) during 2008-09 post-rainy season at Patancheru, India and under normal environment at UAS Dharwad. At Patancheru under normal environment 19 desi (2.7-3. 3 t ha$^{-1)}$ and 12 (2.1 to 3.2 t ha^{-1}) kabuli accessions produced greater seed yield than respective control cultivars, Annigeri (2.4 t ha^{-1}), G 130 (2.1 t ha^{-1}), ICCV 10 (2.5 t ha^{-1}), L550 (2.3t ha^{-1}), KAK 2 (2.01 t ha^{-1}). ICC 15510, ICC 8318, ICC 15610, ICC 3946, and ICC 5383 (3.0-3.3 t ha^{-1}) among desi types and ICC 15435, ICC 9137, ICC 10309, ICC 10569, and ICC 19100 (2.7 – 3.2 t ha^{-1}) among kabuli types were the best high yielding accessions. ICC 11303, ICC 18724, ICC 18983, 19165, and ICC 20266 were the best large seeded kabuli accessions (40-53g). ICC 8318, ICC 9590, ICC 14595, ICC 15518, and ICC 16374 were the earliest flowering lines (38-45 days) under normal environment at Patancheru. Under high temperature environment at Patancheru a total of 29 desi (2.35-2.97 t ha^{-1}) and 14 kabuli type (2.07 to 3.27 t ha^{-1}) accessions produced higher seed yield than respective control cultivars Annigeri (2.34 t ha^{-1}), G 130 (2.31 t ha^{-1}), ICCV 10 (2.25 t ha^{-1}), L550 (2.12 t ha^{-1}) and KAK 2 (2.05 t ha^{-1}). ICC 15510, ICC 8318, ICC 8384, ICC 5639, and ICC 4991(2.7 – 2.97 t ha^{-1}) among desi types and ICC15434, ICC 3410, ICC 9137, ICC 10885, and ICC 15802 (2.90 – 3.27 t ha^{-1}) among kabuli types were the best high yielding lines under high temperature environment at Patancheru. Under normal environment at UAS Dharwad a total of 28 (2.8-3.3 t ha$^{-1)}$ desi and 14 (2.09 to 3.3 t ha^{-1}) kabuli type accessions produced higher seed yield   than respective control cultivars Annigeri (2.4 t ha$^{-1)}$, G 130 (2.8 t ha^{-1}), ICCV 10 (2.2 t ha^{-1}), L550 (2.05 t ha^{-1}), and KAK 2 (2.10 t ha^{-1}). ICC 15510, ICC 8318, ICC 8384, ICC 2969, and ICC 4567 (2.9 – 3.3 t ha^{-1}) among desi type and ICC 15435, ICC 3410, ICC 12037, ICC 7255, and ICC 9137 (2.7 – 3.3 t ha^{-1}) among kabuli types were the best high yielding accessions. ICC 8318, ICC 9590, ICC 14595, ICC 15518, and ICC 16374 were the earliest flowering lines (35- 38 days) under normal environment at Dharwad. ICC 8318 flowers early (34-37 days) and produced high seed yield (2.9 – 3.1 t ha-1) under all the three environments.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, N Lalitha, PM Salimath and CLL Gowda</div>

Reference set of sorghum phenotyped for agronomic traits (2010)

Achievement of Output Target:
75%

Participating Countries:
India, Mali, Kenya, Tanzania, Senegal

Participating Partners:
ICRISAT Patancheru ICRISAT Bamako, ICRISAT Nairobi, UAS Dharwad India, KARI Machakos Kenya, NPGRC Arusha, Tanzania, IER Mali, ISRA/CERAAS, Thies, Senegal.

Progress/Results:

Evaluated sorghum reference set (375 accessions) at ICRISAT- Patancheru, UAS- Dharwad, India; Nairobi- Kenya; and Samako- Mali, during 2008-09 post rainy season. Reference accessions were stratified in 7 groups according to their maturity groups and evaluated under irrigated and induced post-flowering drought conditions at ICRISAT Patancheru. Although the test entries showed large variation for most of the traits, the mean days to 50% flowering was 64 days during rainy season at Dharwad (India) and at Kiboko (Kenya) and 68 days during the rainy season at Samako (Mali). However, the mean days to 50% flowering were 78 days at Patancheru (both under postflowering drought stress and well-watered conditions) and 83 days at Dharwad during the postrainy seasons. Likewise, the mean plant height ranged from 138 to 236 cm across six locations, with lowest height of 138 cm at Samanko under drought stressed conditions. Unlike Samako, no significant difference in mean plant height was recorded among accessions between postflowering drought stressed and well watered conditions during the postrainy season at Patancheru. The trait, panicle exertion (PE), was fully expressed (16-18 cm) at Patancheru and Dharwad (rainy season), while the expression was low (11-12 cm) at Dharwad (postrainy) and Kiboko (Kenya). The accessions at Kiboko and Patancheru showed maximum mean earhead length (23-28 cm) and earhead width (8-9 cm) and least at Dharwad (rainy season: earhead length 19 cm; earhead width 4 cm). The variation in phenology among accessions across locations is probably due to variation in temperature and photoperiod across these diverse locations.

In sorghum, there are five basic and ten intermediate races. In addition to accessions from these races/subraces, this reference set also included some accessions (23) of wild relatives. Phenological differences were also noticed across these races/subraces. For example, subrace *Kafir-caudatum* accessions as group were earliest to flower at five of the six locations (52-62 days), while for this group of accessions, the mean days to flowering during postrainy season at Dharwad was 84 days. For plant height, the guinea-kafir accessions were the shortest with a mean plant height of 157-158 cm, at Patancheru while guinea race accessions were taller with a mean plant height of 267-274 cm, among cultivated types. Durra-caudatum and kafir-bicolor accessions had the maximum panicle exertion (13-23 and 18-25 mm) at three of the five locations. The accessions from the *bicolor* race had recorded maximum mean earhead length and width across locations. Accessions of race Guinea-Kafir race were least affected (27% reduction in grain yield) by the post-flowering drought stress treatment while Kafir-bicolor race accessions were most affected (79% reduction).

The Shannon-Weaver diversity index (H) was calculated to compare phenotypic diversity among sorghum reference set accessions. The index is used as measure of allelic richness and evenness: a low H indicates an extremely unbalanced frequency class for an individual trait and lack of genetic diversity. Plant height (at all the six locations), earhead length (at five locations), days to 50% flowering (at four locations), panicle exertion (at three locations), and basal tillers and earhead width each at one location had H index of over 0.60. The H for basal tillers and earhead length for the remaining locations ranged from 0.46 to 0.58.

Based upon these evaluations we identified 54 drought tolerant accessions with the least difference in response (reduction in grain yield) to the imposed stress or the higher grain yield performance under drought treatment; 45 stay green accessions, 73 accessions with similar or a little reduced (<10%) SPAD chlorophyll meter readings (SCMR) under both stressed and non-stressed conditions ; B35 (having 7 or more leaves at flowering) while an other fraction had lost a smaller number of leaves, being effectively 'stay green', like KS19 (-2 or -3 leaves) as stay green at Samako; IS 18621 (38 days at ICRISAT Patancheru under stressed and non-stressed), IS 28740, IS 9586 (50 days at Samako), IS 28740, IS 3511, IS 30538, IS 28645 (<45 days at Nairobi), IS 18879, IS 4035, IS 28409, and IS 36633 (<45 days at Dharwad) as new sources of early flowering; IS 29991, IS 23601, IS 23574, SSM 215, IS 929, IS 14963 (3.36 – 4.30 t ha^{-1} under non-stressed condition at ICRISAT Patancheru), IS 29991, IS 929, IS 5106, IS 23601, and IS 33423 (3.31 – 3.53 t ha^{-1} under stressed condition at Patancheru) as new donor parents for high seed yield at ICRISAT Patancheru; IS 29991, 23574, and IS 929 as new sources for drought tolerance and high seed yield; IS 18835, IS 31299, IS 11758, IS 11374, IS 20710, IS 22609 (10.6 – 12. 7 t ha^{-1} under non-stress at Patancheru), IS 18835, IS 31195, IS 14556, IS 929, IS 2263, and IS 22939 (10.7 – 12.8 t ha^{-1} under stress) as sources of high fodder yield ; IS 929 as a donor parent for both high fodder and seed yield; IS 7957, IS 26025, IS 7310, IS 15478, IS 7250, IS 25301, IS 7987, IS 15945, IS 1004, and 16382 as tall accessions

Grain and fodder yield has been assessed in PVC tubes mimicking field condition (plant to plant spacing and depth of soil available), in 152 entries of the sorghum reference collection with days to flowering ranging from 69 DAS to 86 DAS (17 days range). The trial has been carried out under terminal moisture stress, applied by providing the last irrigation at 5 weeks after sowing. The range of fodder yield was 26 to 77 g plant^{-1} and grain yield ranged from 0 to 36.7 g plant^{-1}.

Sweet Sorghum Germplasm lines Trial (SSGRDT): A total of 67 germplasm accessions selected from the previously evaluated germplasm accession trial during 2008 postrainy season along with the controls CSH 22SS, SSV 84 and SSV 74, were evaluated in RCBD with three replications. Six accessions IS 23537, IS 23573, IS 23536, IS 23530, IS 23574 and IS 23494 were superior to the best performing control SSV 74 (1.0 t ha^{-1}) for sugar yield ranging from 1.1 to 1.5 t ha^{-1}. These lines flowered in 73 to 77 days (74 days) had a plant height ranging from 1.8 to 2.5 m (2.2 m), Brix% ranging from 14.9 to 18.5 (15.6) and grain yield ranging between 1.9 to 5.0 t ha^{-1} (SSV74 : 2.3 t ha^{-1}).

Sweet Sorghum Zera-Zera lines Trial: A total of 107 zera-zera accessions were evaluated during 2008 postrainy season augmented design. None of the entries were superior to the best control SSV 84 for Brix% 20.8. Three accessions IS 41461 (20.2%), IS 41395 (19.6%), and IS 41460 (19.1%) were better than the check CSH 22SS for Brix%. These lines had plant aspect score ranging from 2.6 to 3.2 (SSV 84: 2.9), plant height ranging from 1.6 to 1.8 m (SSV84: 3.1 m) and days to 50% flowering ranging from 72 to 76 days (SSV84: 79 days).

Sweet sorghum germplasm lines trial (SSGRDT): A total of 78 germplasm lines selected from the germplasm lines evaluated during 2008 postrainy season were evaluated in SSGRDT during 2009 rainy season along with the checks CSH 22SS and SSV 84. The trial was conducted in RCBD in three replications. Though none of the germplasm lines were superior to the best performing control CSH 22SS (4.0 t ha^{-1}) for sugar yield, 18 germplasm lines with a sugar yield ranging from 2.31 to 3.80 t ha^{-1} were numerically superior over SSV 84 (2.27 t ha^{-1}). Of these, the lines IS 23558 (3.8 t ha^{-1}), IS 23562 (3.76 t ha^{-1}), IS 23536 (3.49 t ha^{-1}), IS 23526 (3.48 t ha^{-1}), IS 23574 (3.47 t ha^{-1}), IS 23537 (3.38 t ha^{-1}) and IS 23519 (3.33 t ha^{-1}) were significantly superior to SSV 84. These seven lines flowered from 81 to 108 days (SSV 84: 109 days), had a plant height ranging from 3.2 to 4.1 m (SSV 84: 3.1 m), Brix (%) ranging from 17.1 to 20.2 (SSV 84: 17.1).

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Output target 2011 2.3.5 Core and mini core collections of germplasm evaluated and trait specificity identified

Mini core collections of chickpea, groundnut, and pigeonpea evaluated in multilocations in Asia

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Chickpea mini core collection: chickpea mini core collection was evaluated at ICRISAT Patancheru, IIPR, Kanpur, PAU Ludhiana, UAS Dharwad and Raichur, and at Modipuram in India. Data was recorded on flower color, plant color, growth habit, presence-absence of black dots on seed coat, seed coat texture, seed shape, seed color, days to 50% flowering, podding duration, Plant height, plant width, number of primary, secondary, and tertiary branches, number of pods plant[-1], number of seeds pod[-1], seed weight 100 seeds[-1], seed yield plant[-1] and yield kg ha^{-1}. Large variation was observed for days to 50% flowering, across locations(41-84 days), flowering duration(23-47 days), plant height(18-53 cm), plant width(38-55 cm), days to maturity(102 -122 days), pod plant[-1] (25- 63), seeds pod[-1] (1.0-1.57), 100-seed weight(9.6–44.1g), yield (695 – 1555 kg ha^{-1}), and productivity (5.90 - 14.80 kg ha^{-1}day[-1]). Based on multilocation evaluation, donors were identified for different agronomic characters (Table 11).

Table 11. Trait-specific chickpea germplasm identified from multilocation evaluation of mini core collection.

Character	Range	Desired level	Promising donors
Days to 50% flowering	41 - 84	Early (<45)	ICC 4533,4918,8318,10393,14098,14402, 14495, 6374
Days to maturity	102 - 122	Early (<105)	ICC 1422,4533,5613,10393,13124,14669, 15610, 15618
Plant height (cm)	18 - 53	Dwarf (<25)	ICC 5434
		Tall (>50)	ICC 1915,6306,7323
Plant width (cm)	38 - 55	Compact (<40)	ICC 1422,4533,14669
Pods plant[-1]	25 - 63	More (>50)	ICC708,1098,1164,1710,2263,2629,3218,3362,4872,6571 8950,10393,12866,13892,14831,15868,16207, 16261
Seeds pod[-1]	1.0 – 1.57	More (>1.5)	ICC 7184,12916
100 seed wt.(g)	9.6 – 44.1	High (>35g)	ICC 8151,9137,12328,14199,15406, 15518,16796
Seed yield (kg ha^{-1})	695 - 1555	High (>1500 kg)	ICC 637,1098,3325,3362,4918,7441,8384, 8621,9586,12307,14402,14815,15868
Productivity (kg ha^{-1}day[-1])	5.9 – 14.8	High (>12.5)	ICC 637,1098,2580,3362,7441,8384, 8621,12307,14402,14815,15618,15868
ascochyta blight	Sus. – tol.	Tol.(3.0-5.0)	ICC 1915, 6306, and 11284
botrytis gray mold	Sus. – tol.	Tol. (3.0-5.0)	ICC 1180, 2990, 4533, 4841, 4872, 6263, 6279, 6877, 7255, 7323, 7308, 7315, 7554, 7571, 7668, 7819, 8151, 8261,8318, 8740, 8855, 9137, 9402, 9848, 9862,10341 10755, 10885, 11284, 11764, 11879, 12028, 12037, 12155, 12328, 12492, 13124, 13187, 13219, 13283, 13357, 13461, 13599, 13628, 13816, 14199, 15264, 15294, 15333, 15406, 15435, 15697, 15802, 16796
fusarium wilt	0 – 100 %	0%	ICC 637,1205,1356,1392, 2065, 2072, 2629, 3218, 3230, 4495, 4533, 5613, 6279, 7184, 8058, 13219, 14402, 14669, 16207, 16374, 16903
Pod borer tol.	Sus.- -tol.	tolerant	ICC 3218, 9862, 14595, 15294, 15518
drought tolerance	Sus. – tol.	tolerant	ICC 67, 506, 867, 2263, 3325, 3512, 6571, 8261, 8350,14402, 14778, 14799, 15697
salinity tolerance	Sus. – tol.	(>60% of normal yields)	ICC 456, 708, 791, 867, 1710, 2263, 3325, 3512, 4639, 4657, 4918, 5613, 5639, 5845, 6279, 6811, 6874, 7668, 8384, 9942, 11121, 11284, 12155, 12851, 12866,14051 14077,14402,14595,14799,14815,15264,15606,16915
Seed protein	9.26 – 30.5	>25%	ICC 2263, 6579, 6811, 12654, 12851, 13461

Groundnut mini core collection: The high oil and protein contents of groundnut serve important needs for food and quality. A minicore comprising 184 accessions was developed representing the ICRISAT global groundnut collection. The minicore set of 184 groundnut accessions mainly comprised three botanical varieties viz, 85 accessions of var. *hypogaea*, 58 accessions of *vulgaris* and 37 accessions of *fastigiata*. Two accessions of var. *peruviana* and one accession each of var. *aequatoriana* and var. *hirsuta* were also represented. Four control cultivars, Gangapuri (var. *fastigiata*), ICG 44 (var. *vulgaris*), and ICG 76 and M 13 (var. *hypogaea*) were included in all trials for comparison. The groundnut minicore set was evaluated in 19 environments at Durgapura Jalgaon Raichur Kawadimatti, ICRISAT Patancheru in India, and in Thailand, Vietnam, and China during both rainy and postrainy seasons. Data were recorded for 16 agronomic traits viz. days to emergence, days to flower, number of primary branches, plant height, leaf length, leaf width, and days to maturity, pod length, pod width, seed length, seed width, pods per plant, yield per plant, pod yield, shelling percentage and seed weight. Five additional characters viz. haulm yield, specific leaf area at 60 and 80 days after sowing, and Soil-Plant Analyses Development (SPAD) chlorophyll meter reading at 60 and 80 days after sowing were recorded only at ICRISAT location. Protein content (%) and oil content (%) at ICRISAT, Raichur, Kawadimatti and Thailand; rust incidence at Vietnam; peanut bud necrosis disease incidence at Raichur and Kawadimatti, and late leaf spot incidence at Vietnam were also recorded. Incidence of bacterial wilt and fatty acid profiles of groundnut oil (Palmitic acid, Stearic acid, Oleic acid, Linoleic acid, Arachidic acid, Eicosenoic acid, Behenic acid and Lignoceric acid) was additionally recorded at Dharwad. A wide range of variation was observed among the agronomic traits. The range of trial means across locations ranged from 23 to 50 days for 50% flowering, pods per plant 9.6-63.7 pods, shelling percentage53.7-74.6%, 100-seed weight 25.4-58.6g, and pod yield 0.49-2.89 tha[-1].

Based on these multilocation evaluations we identified sources for various traits. ICGs 332, 3681, 3775, 4750, 5609, 6201, 6703, 6407, 8083, 10566, 11144, and 13858 as new sources for **early flowering**; ICGs 4543, 4729, 9809, 12687, 12879, and 12988 for **pods plant^{-1}**; ICG 1698 for **plant yield^{-1}**; ICGs 36, 1519, 3992, 5195, 5236, 8083, 9037, 9157, 9809, and 12988 for **shelling percentage**; ICGs 2381, 5016, 5051, 5745, 5662,6057, 6766, 8760, 11219, 11855, 11862 and 14482 for **large seed size**; ICGs 5745, 6646, 10036, 11088, 13099, and 15419 for **plot yield**; ICGs 4670, 6022, 6888, 10036, 11088 for **low temperature tolerance** at germination; ICGs 118, 532, 862, 2106, 2511, 2773, 4527 5236, 5827, 6654, 6766, 7243, 8285,11219, 14985,14475, 11885, and 14523 for SCA and SCMR traits related to **drought tolerance**; ICGs 36, 81, 434, 442, 1415, 3053, 3421, 3673, 7969,and 11515 for **water transpiration efficiency**; ICGs 442 , 1519, 1711, 2106, 5195, and 7283 for **salinity;** ICGs 721, 14466, and 1668 for **bud necrosis** disease; ICGs 2857, 2862, 2381, 5662, 6027,6667, 8760, 9777, 11219, 12625, and 13787 for **confectionary type**; ICGs 297, 2381, 2857, 2995, 5286, 5546, 5609, 5662, 5663, 8285, 9249, 9507, 9961, 11426, 11651, 12625, 12672, 12879, 13600, 13858, 14775, 14882, and 14985 for **multiple traits**; ICGs 36, 118, 442, 1101, 3421, 3584, 4750, 5779,6022, 8016, 8567, 10890, 12672, and 14882 for **oil content**; ICGs 397, 442, 4955, 12000, and 14710 for **protein content**; ICGs 2381, 3053, 5745, 6022, 6913, 8285, 8490, 10185, 11088, 12276, 12625, and 15419 for **oleic acid**; ICGs 188, 397, 3053, 4955, 5745, 8285, 8490, 9418, and 14710 for **linoleic acid**; ICGs 2381, 3053, 5745, 6022, 6913, 6766, 7243, 8285, 8490, 10185, 11088, 12276, 12625, 15190, and 15419 for **oleic linoleic acid ratio;** ICGs 2587, 2857, 6022, 6402, 8760, 11426, 12625, 12672, and 13787 for **late leaf spot**; ICGs 2857, 6022, 6402, 10890, and 11426 for **early leaf spot**; ICGs 513, 532, 2857, 2925, 3992, 4412, 4746, 5327,6022, 6706, 8490, 8760, 9809, 9842, 9961, 10036, 11088, 10890, 11109, 11426, 11575, 12000, 12697, 13099, and 13787 for **rust**; ICGs 36, 76, 118, 397, 434, 1415, 1455, 1448, 5745, 1668, 6057, 6201, 7633, and 14710 for **bacterial wilt**; ICGs 3673, 6025, 8760, 12625, 13787, and 14985 for *A flatus;* and ICGs 8760, 12625, and 13787 for **multiple resistance**.

Pigeonpea mini core collection: Evaluated pigeonpea mini core collection and four control cultivars of extra early (ICPL 87), early (UPAS 120), medium (Maruti) and late (Gwalior 3) maturing groups at Bangalore, Dholi, Dantiwada, Jalna, Kanpur, Khargoneand Patancheru locations in India. Wide range of variation was observed in mini core at all locations. Days to 50% flowering at Khargone, ranged from 79 - 136 days, plant height from 85 - 231 cm, primary branches per plant 2 - 9, pods per plant from 2 - 169, 100-seed weight from 4 - 17 g and seed yield per plant from 1 - 37 g. Several germplasm accessions were better as compared to extra early and medium maturing controls for seed yield per plant. 19 accessions in extra early group and 10 accessions in medium maturity group for high harvest index compared to respective control cultivars at Khartoum were identified. ICP 14900 and ICP 1156 as donor parent for early flowering and high seed yield in extra early group and ICP 1156 and ICP 15068 (91 days) were identified as new sources for early flowering compared to control cultivar ICPL 87 (93 days) at Khartoum. Days to 50% flowering at Dhoti ranged from 49 to 187 days; plant height from 100 to 275 cm; primary branches from 3 to 39; pods per plant from 2 to 740; 100 seed weight from 6 to 16 g and seed yield per plant from 4 to 70 g. Identified ICP 14471, ICP 14903, ICP 16309, ICP 15068, ICP 14832 and ICP 9336 as sources for extra early flowering compared to control cultivar ICP 11543 at Dhoti. Days to 50% flowering at Patancheru ranged from 72 to 165; plant height from 120 to 257; primary branches from 8 to 29; pods per plant from 71 to 692; seeds per pod from 2.7 to 5.5 and 100 seeds weight from 5 to 18. ICP 16309 (72 days) for extra early flowering, ICP 8860 (29) for primary branches, ICP 5860, ICP 11230, ICP 4167, ICP 8602 for pods per plant, and ICP 14976, ICP 13359 and ICP 13139 (100 seed weight > 16g) were found promising as new sources at Patancheru

Special Project Funding:
NA

HD Upadhyaya, HC Sharma, RP Thakur, S Pande, KL Sahrawat, CLL Gowda, NARS Scientist in India, China, Vietnam, and Thailand

Output target 2009 2.3.1
Mini core collection of pigeonpea germplasm evaluated for resistance to wilt and sterility mosaic diseases under controlled environment and field conditions (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Confirmation of pigeonpea mini-core collections for resistance to Wilt and SMD: Fifty five wilt and sterility mosaic disease resistant lines from pigeonpea mini-core were evaluated for confirmation of resistance to both the diseases under artificial epiphytotic conditions in field. One line (ICP 11015) was found resistant (0.1- 10% incidence) and three lines moderately resistant (10.1-20 % incidence) to both FW and SMD. For FW, one line (ICP 6739) was found asymptomatic (0 % incidence), one line (ICP 11015) resistant (0.1- 10% incidence) and three lines moderately resistant (10.1-20 % incidence). For SMD, 3 lines were asymptomatic (0 % incidence) and 1 line resistant (0.1- 10% incidence).

Confirmation of chickpea reference set for resistance to AB: Reference set consisting of 300 lines was evaluated for confirmation of resistance to ascochyta blight (AB) under controlled environment conditions. Five lines (ICCS 4363, 4918, 6293, 19122 and 19147) were resistant (≤3 rating on 1-9 scale) and 28 moderately resistant (≤5 rating on 1-9 scale) to AB.

Special Project Funding:
NA

Suresh Pande, Mamta Sharma, HD Upadhyaya and CLL Gowda

Mini core collection of pigeonpea germplasm evaluated for resistance to *Helicoverpa* (2010)

Achievement of Output Target:
100%

Participating Countries:
India, Ethiopia, Kenya, and Tanzania

Progress/Results:
Evaluation of pigeonpea germplasm for resistance to pod borer, *Helicoverpa armigera*: We evaluated 146 pigeonpea germplasm accessions for resistance to *H. armigera* along with resistant and susceptible checks under field conditions using three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery, resistance on a 1 to 9 rating scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), and grain yield. The genotypes ICP 7, ICP 655, ICP 772, ICP 1071, ICP 3046, ICP 4575, ICP 6128, ICP 8860, ICP 12142, ICP 14471, and ICP 14701 exhibited moderate levels of resistance (damage rating 5.0 as compared to 9.0 in ICPL 87) to pod borer, *H. armigera* and these lines also showed good yield potential (> 8.5 to 15.4 q ha^{-1}) under unprotected conditions, and also had no wilt incidence as compared to 38.2% wilt in ICP 8266.

Evaluation of mini core collection as part of reference set of chickpea for resistance to pod borer, *Helicoverpa armigera*: Reference collection (305 lines), including the resistant (ICC 506 EB), and the susceptible (L 550) checks was evaluated for resistance to pod borer, *Helicoverpa armigera* during the 2008/09 postrainy season at ICRISAT-Patancheru, India, using three replications in a randomized complete block design. The test material was sown on ridges, 60 cm apart. There were two rows for each plot, 2 m long. The plants were thinned to a spacing of 10 cm between the plants at 15 days after seedling emergence. Normal agronomic practices were followed for raising the crop, but there was no insecticides application in the experimental plots. Data were recorded on leaf and pod damage, egg and larval density per 10 plants, overall resistance score, and grain yield. The material was also evaluated for resistance to *H. armigera* using detached leaf assay at the vegetative (30 days after seedling emergence) stage. For this purpose, the terminal branches (5 – 7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

In detached leaf assay at the vegetative stage (30 days after seedling emergence), leaf feeding scores ranged from 1.67 – 7.98 (mean 3.98), and compared to 3.67 on ICC 506 and ICC 3137. Larval weights ranged from 0.58 – 5.65 mg (mean 2.80 mg) compared to 1.91 mg on ICC 506, and 2.94 mg on ICC 3137. Many lines suffered low feeding damage and also had lower larval weight gains comparable to the resistant check, ICC 506, and further screening of these lines will result in identification of genotypes with antifeedant and/or antibiosis mechanism of resistance to *H. armigera*.

Under natural infestation in the field, leaf feeding scores varied from 3.5 – 7.5 in the reference collection, 5.5 in ICCV 10, and 5.0 in ICC 3137 during the vegetative phase. There were 0.0 – 9.0 larvae per 5 plants in the reference collection, 4.0 in ICCV 10, and 5.5 in ICC 3137. During the reproductive stage, there were 0.0 – 17.0 larvae per 5 plants in the reference collection, 3.5 in ICCV 10, and 6.0 larvae in ICC 3137. Overall resistance scores ranged from 3.0 – 8.0 with a mean of 6.25 in test entries, ICCV 10 (3.5) and ICC 3137(7.0). Pod damage ranged from 3.5 - 86.9% in the reference collection, 12.9% in ICCV 10 and 24% in ICC 3137. The grain yield of the test lines ranged from 100 – 2,530 kg ha^{-1}, The genotypes showing lower susceptibility to damage by *H. armigera* and a yield potential of >1,000 kg ha^{-1} under unprotected conditions will be distributed to NARS partners for use in breeding programs or for on-farm testing for use by the farmers. The results indicated that there is considerable variation in the reference collection for resistance/susceptibility to *H. armigera*, and selections based on detached leaf assay, and field performance of the lines can be used for developing breeding populations with resistance to pod borer.

HC Sharma, HD Upadhyaya and N Lalitha

Groundnut germplasm evaluated for insect defoliation and bud necrosis: During 2008-09 post-rainy season 687 groundnut germplasm accessions were evaluated for resistance to bud necrosis disease and insect defoliation under field condition. Among the defoliating insect pests, *Spodoptera litura* was the most significant one. Based on the previous three seasons performance 20 lines were selected with resistance to BND (< 1),defoliation (< 5%) and high yield (2.25-4.25 t ha^{-1}) compared to standard checks, M 13, Gangapuri, ICGS 44, ICGS 76 (0.78-1.11 t ha^{-1}). These lines will be further evaluated in sprayed and UN sprayed situations in the coming season.

GV Ranga Rao, HD Upadhyaya and CLL Gowda

Sorghum mini core collection evaluated for resistance to grain mold and anthracnose (2010)

Achievement of Output Target:
75%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Of 242 sorghum minicore accessions grown for evaluation of grain mold resistance in 2007 only 140 flowered for which grain mold scoring was done. The same set of 140 accessions and one resistant (IS 8545) and 3 susceptible (SPV 104, Bulk Y and H 112) controls were screened for resistance to grain mold and anthracnose in the 2008 rainy season in the respective disease nurseries. The mini core accessions (242) were re-evaluated in rainy season 2009 for anthracnose resistance.

Resistance to grain mold: Based on mean grain mold severity for two years (2007-08), 53 accessions were found resistant (grain mold severity ≤10%), 32 moderately resistant (11 to 30%), 25 susceptible (31 to 50%) and 30 highly susceptible (mold severity >50%) compared to 83 and 88% severity in susceptible checks SPV 104 and Bulk Y, respectively, and 2% severity in resistant check IS 8545. Fifty accessions were found resistant in both the seasons indicating stable resistance.

Resistance to anthracnose (*Colletotrichum graminicola*): During the 2008 rainy season screening, none of the140 lines were free from anthracnose; 10 were resistant (≤3.0 score); 10 moderately resistant (3.1-5.0 score) and the remaining 120 susceptible (5.1-9.0 score) compared to 2.5 score in resistant checks (IS 10302 and IS 20956) and 9.0 in the susceptible check (H 112). Of the 242 minicore accessions screened by artificial inoculation during the rainy season 2009, 9 were resistant (score ≤3.0), 71 moderately resistant (score 3.1-5.0), 109 susceptible (score 5.1-7.0) and the remaining 53 highly susceptible (score >7.0). Six accessions ISs 10302, 20956, 19153, 10969, 12945 and 23521 were resistant in both years (2008 and 09) indicating stable resistance.

Resistance to both grain mold and anthracnose: Three lines (IS 20956, IS 2379 and IS 10969) were found resistant to both anthracnose and grain mold whereas 17 were moderately resistant (3.1 – 5.0) to both diseases.

RP Thakur, R Sharma and HD Upadhyaya

Reference collection characterized for *Helicoverpa* resistance

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Resistance to pod borer (*Helicoverpa armigera*): The 300 reference set accessions were evaluated along with resistant (ICC 506) and susceptible (L 550) controls for resistance using detached leaf assay at vegetative (30 days after seedling emergence) stage. The terminal branches (5 to 7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation. A total of 34 (<3.0) reference lines were better than the resistant control cultivar ICC 506-EB for leaf feeding score. The best five reference lines were ICC 5878, ICC 6877, ICC 11764, ICC 16903, and ICC 18983(1.0-2.3) for leaf-feeding score under detached leaf assay screening as compared ICC 506-EB (3.1). A total of 63 reference accessions has lower larvael (37-60%) survival rate compared to resistant control cultivars ICC 506-EB (63%). The best five accessions for least larvaal survival rate were ICC 12537, ICC 9590, ICC 7819, ICC 2482, and ICC 4533 (37 – 47%). Larvae weight ranged from 1.2 to 13.1 mg larva^{-1}. A total of 47 reference accessions (<2.3 mg) showed lower larvae weight compared to resistant control cultivar ICC 506-EB (2.3 mg). ICC 16903, ICC 6877, ICC 3946, ICC 11746, and ICC 18983 (1.2 – 2.1 mg larva^{-1}) were the best five accessions for lower larvae weight.

HC Sharma, HD Upadhyaya and N Lalitha

Sorghum mini core collection evaluated for resistance to leaf blight and downy mildew (2011)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Resistance to leaf blight (*Exserohilum turcicum*): Of the 140 accessions screened during the post-rainy 2008-09, 44 were resistant (≤3.0 score), 73 moderately resistant (4-5 score) and the remaining 23 susceptible (6-9 score) to leaf blight. The entire minicore collection (242 accessions) is being screened during the 2009-10 post rainy season.

Resistance to downy mildew (*Peronosclerospora sorghi*): The 242 minicore accessions were evaluated in a greenhouse along with a susceptible control (296 B) and a resistant check (QL 3) using a sandwich inoculation technique. Of the 242 accessions, 6 were resistant (≤10% incidence), 2 moderately resistant (11 to 20% incidence), 14 susceptible (21-30% incidence) and the remaining 220 highly susceptible compared to 100% incidence in the susceptible check (H 112) and 23% in the resistant check (QL 3). Among the resistant accessions, IS 28747 was free from downy mildew, two accessions (IS 31714 and IS 23992) recorded ≤5% downy mildew, while three (IS 27697, IS 28449 and IS 30400) had 6 to 10% incidence.

Resistance to rust (*Puccinia purpurea*): Of the 140 minicore accessions evaluated for rust resistance under natural disease pressure during the post rainy 2008-09, 10 (IS 3121, IS 20956, IS 21512, IS 21645, 19153, IS 23521, IS 29950, IS 29239, IS 28449 and IS 473) were rust free, 84 (60% of the lines) resistant (≤10% severity), 25 (18% lines) moderately resistant (11-20% severity), 15 (11% lines) susceptible (21-30% severity) and 6 (4% lines) were highly susceptible (>30% severity) compared to 90% severity in a susceptible check H 112. The entire minicore comprising 242 accessions is being screened in field under natural infection for rust during the post rainy season 2009-10..

Resistance to multiple diseases: One accession IS 23992 showed resistance to all the five diseases (downy mildew, anthracnose, leaf blight, rust, and grain mold); three (IS 21512, IS 21645 and IS 20743) to anthracnose, leaf blight, rust and grain mold; one (IS 26694) to

anthracnose, leaf blight and rust; seven (IS 13971, IS 16151, IS 29187, IS 29314, IS 29335, IS 29326 and IS 1212) to leaf blight, rust and grain mold; while several others were also resistant to any two of the five diseases.

Special Project Funding:
NA

RP Thakur, R Sharma and HD Upadhyaya

Pearl millet mini core collection evaluated for resistance to rust (2012)

Achievement of Output Target:

Include a very short paragraph (2-5 sentences) providing rationale for the indicated achievement:

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Not reported during 2009

Special Project Funding:
NA

Output target 2011 2.3.3

Pearl millet mini core collection evaluated for resistance to downy mildew (2011)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Downy mildew (DM) a disease of pearl millet caused by *Sclerospora graminicola* (Sacc.) Schroet, is a major biotic constraint severely limiting the production and productivity of the crop in the SAT environment. The most effective and reliable management of this disease can be achieved only through resistance cultivar. High level of DM resistance is pre-requisite for a cultivar to be released for commercial cultivation in India and elsewhere. Pearl millet germplasm collection, particularly the recently developed minicore set could provide some good sources of genetic resistance to this disease, although a number of resistance sources are already available.

Pearl millet mini core comprising of 238 accessions and three controls (IP3616, IP 17862 and IP 22281) were evaluated for downy mildew (DM) resistance in the DM sick plot using the infector-row system at Patancheru. The lines were evaluated along with susceptible checks 7042S and PMB 11571-2 planted after every 8 test rows. The experiment was conducted in a RCBD with 2 replications; 1 rows of 4 m length/replication. High humidity (>90%RH) was maintained using overhead perfo irrigation for about 15 days after planting to the test rows to facilitate disease development. Total number of plants and downy mildew infected plants per plot/entry were recorded at the pre-tillering stage (about 30 days after emergence) and at the soft-dough stage (about 60 days after emergence). The disease incidence data at the soft-dough stage was considered for comparison, as there was increase in incidence in some entries at the later stage. Of the 238 accessions, 8 (IPs 8418, 9934, 10263, 11405, 11428, 11930, 17775, 20715) were DM free, 121 resistant (≤10% incidence), 46 moderately resistant (11-20% incidence), 39 susceptible (21-30% incidence) and the remaining 24 highly susceptible (>30% DM incidence). The accessions found resistant in the field will be evaluated in the greenhouse against diverse pathotypes to identify genetically diverse DM resistant accessions for use in DM resistance breeding program.

Special Project Funding:
NA

RP Thakur, R Sharma and HD Upadhyaya

Finger millet core collection evaluated for agronomic traits in Asia and Africa (2009)

Achievement of Output Target:
100%

Participating Countries:
India, Kenya, Tanzania, Uganda, and Germany

Participating Partners:
Acharya N G Ranga Agricultural University, Rajendranagar, India; University of Agricultural Sciences, Bangalore, India; Rajendra Agricultural University, Dholi, India; Kenya Agricultural Research Institute; Agricultural Research Institute, Tanzania; National Semi-Arid Resources Research Institute, Uganda; and University of Hohenheim, Germany

Progress/Results:
A total of 622 accessions of the finger millet core collection and controls (IE-2043, IE- 3618, IE-4673, VR708, and two local control cultivars) were grown in alpha design with two replications during 2008 rainy season at five locations in (Nandyal, Vizianagarm, and

Patancheru in Andhra Pradesh, Mandya in Karnataka, and Dholi in Bihar) India. Likewise, 76 accessions representing the entire diversity in core and 24 controls from NARS were evaluated in 10x10 simple lattice design at one location each in Kenya, Tanzania, and Uganda during 2008. At all locations, observations on days to 50% flowering, plant pigmentation, plant height (cm), growth habit, number of basal tillers, number of culm branching, flag leaf blade length and width (mm), flag leaf sheath length (mm), peduncle length (mm), panicle exertion (mm), inflorescence length and width (mm), length and width of longest finger (mm), fingers per ear head, inflorescence compactness, lodging, overall plant aspect score, plot yield (g), grain color, and blast (neck and finger) resistance were recorded on five plants per plot. Leaf blast incidence was recorded on plot basis. Wide of variation among the accessions tested was observed. Mean seed yield ranged from 0.02 to 2.74 t ha^{-1} in Kenya; 0.68 to 0.94 t ha^{-1} in Uganda; 2.20 to 2.27 t ha^{-1} at Patancheru, 0.95 to 2.53 t ha^{-1} at Nandyal, 0.09 to 0.92 t ha^{-1} at Bangalore, and 0.24 to 2.43 t ha^{-1} at Dholi, India. Based on these data promising lines for different traits and locations have been identified (Table 12 -13).

Table 12. Select genotypes and range at different locations against common controls in finger millet (PR202, RAU8, VL149, VR708 and two locals).

Character	Genotypes	Mandya	Nandyal	Patancheru	Vizayanagaram	Dholi
Early flowering (days)	Controls	59-80	54-70	58-75	49-68	35-54
	Promising lines	<52 (IE196, 3543, 2622, 7505, 588)	51-54 (IE501,588,4734, 2322, 3543)	46-51 (IE4709, 6013, 2322, 4708, 588)	42-46 (IE5817, 501, 4734, 588, 5736)	32 (IE6417)
High grain yield (t/ha)	Controls	1.6-3.8	1.8-2.1	2.23-2.25	40.8-50.5 (g/plant)	0.83-1.88
	Promising lines	4.0-5.6 (IE3559, 5179, 3566, 3028, 7346)	2.2-2.5 (IE3435, 5321, 667, 2999, 3317)	2.27-2.28 (IE 4403,4383, 6417, 5105,4646)	52.1-56.3(g/plant) (IE6645, 2235, 224, 3196)	2.65-2.71 (IE5179, 5364)

Table 13. Newly identified donors for different characters in finger millet.

Character	Desired level	Promising lines
Early flowering (days)	55-57	IE 2872,2957,U-15
Finger number	8-9	IE 3945,4057,5091,5870,6337
Neck and finger blast	resistance	IE 1239,1290,1294
High grain yield (t/ha)	1.66-2.74	B1(A), SERERE(1), IE 3973, Adoke,SEREMI-1,2,3, U-15, GBK28463, IE 2440,1055, 3614, 3127, 4073, 5165,SARADA, GBK 29661, IE4757, 4329,3392, 4795 (Kenya); IE4057,4671,GBK296,PESE1,SAVADA (Uganda)
Protein (%)	8.4 – 11.1 (controls: 6.74-8.2)	IE 3443,4443,4476,4709,4817,6546,2931,4709, 588,942,6537,3120,6541
FE (mg/kg)	37.7 – 88.4 (controls: 24.7-30.7)	
Zn (mg/kg)	21.7 – 31.1 (controls: 17.8-22.9)	
Ca (g/kg)	2.8 – 5.1 (controls:2.7-3.1)	

IE 3693, IE 5165, IE 5367, IE 5066, and IE 3979 (82-83g plant^{-1}) for high shoot weight, IE 4671, IE 4673, and 2957 (12.9-23.8g plant^{-1}) for high panicle weight, and IE 3614, IE 5367, IE 4673, IE 5165, and IE 5066 for TE under drought stressed condition upon evaluation of 100 finger millet core accessions. IE 5367, IE 4673, IE 5165, and IE 5066 had greater shoot weight, panicle weight, and high TE, the traits related to drought tolerance.

HD Upadhyaya, NDRK Sharma, Y Narasimhudu, CR Ravishankar, SK Varshney, SK Singh, V Vadez, RP Thakur, COA Oduori, DB Kisandu, N Wanyera and HK Parzies

Foxtail millet core collection evaluated for agronomic traits in India (2010)

Achievement of Output Target:
80%

Participating Countries:
India

Participating Partners:
ICRISAT, Acharya N G Ranga Agricultural University, Rajendranagar, India; University of Agricultural Sciences, Bangalore, India; Rajendra Agricultural University, Dholi, India

Progress/Results:
The 155 foxtail millet core collection accessions and four common controls (ISe-375, ISe-376, ISe-1468, ISe-1541), and a local control were grown in alpha design with three replications during 2008 rainy season at five locations (Nandyal, Vizianagarm, and Patancheru in Andhra

Pradesh, Mandya in Karnataka, and Dholi in Bihar) in India. Observations on days to 50% flowering, plant pigmentation, leaf color, plant height (cm), growth habit, basal tillers, culm branching, flag leaf blade length and width (mm), flag leaf sheath length (mm), peduncle length (mm), panicle exertion (mm), inflorescence length and width (mm), bristle length, panicle lobing, inflorescence compactness, lobe compactness, grain color, weight of 5 panicles (g), lodging, overall plant aspect, leaf senescence, and blast resistance were recorded on five plants per plot. A wide variation range among the accessions tested was observed. Based on these data promising lines for different traits and locations have been identified (Tables 14 & 15).

Table 14. Select genotypes and range at different locations against common controls in foxtail millet (ISe-375, ISe-376, ISe-1468, ISe-1541 and one local).

Character	Genotypes	Mandya	Nandyal	Patancheru	Vizayanagaram	Dholi
Early flowering (days)	Controls	57-62	53-59	53-60	39-57	49-63
	Promising lines	38-40 (ISe1312, 1227, 1286, 1234, 1368)	33-50 (ISe302,507, 1227, 1402,1406)	30-35 (ISe1151,1320, 1254,1234, 1335)	22-33 (ISe1227, 1181, 1204,1563,1647)	23-30 (ISe1858,1312 1335,1201, 1286)
High grain yield (kg/ha)	Controls	452-654	1.0 (g/plant)	667-1852	4.8-6.9 (g/plant)	7.3-9.0 (g/plant)
	Promising lines	810-919 (ISe1888, 338,364, 842, 1808)	2.2-2.9(g/plant) (ISe783,1269, 1780,388)	2122-2350 (ISe710,1354,909, 8692, 1820)	7.2-8.5 (g/plant) (ISe1575,745,254, 710, 1900)	11.1(g/plant) (ISe1745)

Table 15. Newly identified donors for different characters in finger millet.

Character	Range	Promising lines
Ca content (ppm)	107-152 (controls)	ISe-375, ISe-376, ISe-1468, ISe-1541
	193-289 (promising lines)	ISe 751, 827, 840, 900, 1059, 1181,1227,1419,1474, 1685
Fe content (ppm)	40-49 (controls)	same
	62-68 (promising lines)	ISe 144, 1059, 1151, 1286, 1305, 1312,1320,1332,1400,1581
Zn content (ppm)	41-52 (controls)	same
	56-74 (promising lines)	ISe 195, 748, 900, 1134, 1161, 1286,1387,1408,1419,1820
Protein (%)	11-16 (controls)	same
	16.1-18.5(promising lines)	ISe 748, 751, 827, 1227, 1254, 1305, 1312,1335,1647,1789
B-carotene (ug/100g)	<100 (controls)	same
	>100 (promising lines)	ISe 315,375,398,403
Salinity tolerance	*Controls:* Shoot wt./plant (18.9-51.2g) Seed wt./plant (7.0-14.28g) Harvest index (0.21-0.30)	same
	Promising lines: Shoot wt./plant (54.1-76.1g) Seed wt./plant (18.9-29.8g) Harvest index (0.28-0.33)	ISe 254, 869, 1851, 96, 388, 480, 995,1629,969,1888
Drought tolerance	*Controls:* Shoot wt./plant (28.3-63.5g) Seed wt./plant (11.2-13.7g) TE (3.6- 4.7)	same
	Promising lines: Shoot wt./plant (49.91-67.7g) Seed wt./plant (11.2-18.3g) TE (4.7- 4.8)	ISe 507, 1468, 771, 1858, 238, 1767,795,289,1846,1234

HD Upadhyaya, NDRK Sharma, Y Narasimhudu,
CR Ravishankar, SK Varshney, SK Singh, V Vadez,
RP Thakur, R Sharma and KL Sahrawat

Finger millet core collection evaluated for resistance to blast disease (2010)

Achievement of Output Target:
75%.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Blast disease of finger millet [*Eleusine coracana* (L.) Gaertn.] caused by *Pyricularia grisea* (Cooke) Sacc. (teleomorph- *Magnaporthe grisea*) is a major problem in India and Africa causing substantial yield losses. This disease can best be managed through host plant

resistance. In this project, the major focus has been to screen the core and minicore collections of finger millet that are available at ICRISAT Gene bank to identify genetic resistance to this disease.

During the past 2 years, considerable progress has been made in establishing pure cultures of the pathogen, developing field screening technique, screening and identifying some accessions resistant to neck and finger blast described below:

Finger millet core (622) and minicore (80) germplasm accessions of were planted in 1 row of 2m plot in two replications in RCBD. Susceptible checks (VL 149, VR 708, RAU 8 and PR 202) were planted on every 5th row alternatively. Plants were thinned to 20 plants/row 15 days after planting and other agronomic practices were followed as per local practices. Plants were spray-inoculated at pre-flowering stage with an aqueous conidial suspension (1×10^5 spores ml^{-1}) of *P. grisea* fm-strain grown on oat-meal agar medium at 28ºC for 7 days. High humidity was provided by perfo-irrigation twice a day on rain-free days, 30 min each in the morning and evening hours to facilitate the disease development.

Leaf blast was recorded using a progressive 1-9 scale, where 1= no infection and 9=>75% leaf area infected with typical lesions of blast. Neck blast incidence was recorded at the dough-stage using a 1-5 scale, where 1= pinhead size lesions, 2= 1.0-2.0cm, 3= 2.1-3.0cm, 4= 4.1-6.0cm, 5= >6.0 cm lesions on the neck region. Finger blast severity (%) estimate was recorded across all panicles in a row. Most of the lines were free from leaf blast and only a few lines recorded leaf blast with <2.0 score.

Based on neck blast rating, the accessions were categorized in to: highly resistant (score 1.0), resistant (1.1-2.0), moderately resistant (2.1-3.0), susceptible (3.1-4.0) and highly susceptible (4.1-5.0). Similarly, based on finger blast severity (%), accessions were classified into: highly resistant (0-1.0%), resistant (2-10 %), moderately resistant (11-20%), susceptible (21-30%) and highly susceptible (>30%).

Neck and finger blast resistance: Of the 80 minicore accessions screened, 4 (IE 2821, IE 2911, IE 4057 and IE 4073) were highly resistant (score 1.0 on 1-5 scale) to neck blast whereas only one (IE 4709) was resistant to finger blast (0% incidence); 56 accessions were resistant to both neck and finger blast, and 4 (IE 501, IE 6082, IE 4734 and IE 5870) highly susceptible comparable to the susceptible checks (VL 149 and VR 708).

Of the 622 core accessions, 19 were highly resistant and 323 resistant to neck blast whereas 28 were highly resistant and 342 resistant to finger blast. About 300 accessions were found resistant to both neck and finger blast. Similar data on minicore lines were obtained from four other locations – Mandya, Naganalli, Nandyal and Vizianagaram. These data sets are being analyzed to identify stable resistant lines. Some of the minicore lines that showed resistance to both neck and finger blast across five locations are: IE 2589, IE 2871, IE 2911, IE 2957, IE 4497, IE 6337 and IE 7018, and some of the susceptible across locations are: IE 196, IE 501, IE 518, IE 2293, IE 2322, IE 2323, IE 4734, IE 4755, IE 4757, IE 6082 and VR 708. It would be important to confirm the resistance of these lines by screening again by artificial inoculation both in the field and greenhouse.

RP Thakur, R Sharma, HD Upadhyaya, CLL Gowda, CR Ravikshore,
NDRK Sharma, Y Narasimhudu, SK Varshney, SK Singh,
COA Oduori, DB Kisandu, N Wanyera and HK Parzies

Output target 2011 2.3.1
Foxtail millet core collection evaluated for resistance to blast disease (2011)

Achievement of Output Target:
50%
Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Blast disease of foxtail millet [*Setaria italica (L.*) P. Beauv.] caused by *Pyricularia grisea* (Cooke) Sacc. (teleomorph- *Magnaporthe grisea*) is a major problem in India and Africa causing substantial yield loss. Management of this disease can best be managed through host plant resistance. In this project, the major focus has been to screen the core collection of foxtail millet that is available at ICRISAT Gene bank to identify genetic resistance to this disease.

The first step to screening was to establish a pure culture of the pathogen and develop an effective screening technique. During the year, a pure culture was established, an artificial field screening technique developed and the core collection screened as described below.

Foxtail millet core collection comprising of 159 accessions were grown at Patancheru in a randomized block design with 1 row (2m) x 2 replications. Plants were spray-inoculated at pre-flowering stage with an aqueous conidial suspension (1×10^5 spores ml^{-1}) of *P. grisea* fxm-strain grown on oat-meal agar medium at 28ºC for 7 days. High humidity was provided by perfo-irrigation twice a day on rain-free days, 30 min each during morning and evening hours to facilitate the disease development. Foliar and neck blast scores were taken at the dough stage as described above for finger millet blast. Most accessions were free from foliar blast and only four (ISe 1129, ISe 1299, ISe 1037 and ISe 1118) were susceptible to foliar blast. Neck blast scores were highly variable and 20 accessions (ISe 375, ISe 480, ISe 748, ISe 751, ISe 769, ISe 1037, ISe 1067, ISe 1204, ISe 1320, ISe 1335, ISe 1387, ISe 1419, ISe 1547, ISe 1593, ISe 1685, ISe 376 and ISe 1541) were resistant to neck blast. These results need to be confirmed.

RP Thakur, R Sharma HD Upadhyaya and CLL Gowda

Groundnut mini-core collection screened for root traits (2010)

Achievement of Output Target:
100%

Participating Countries:
Malawi, Tanzania, Senegal, Niger

Participating Partners:
National program of Malawi, Tanzania, Senegal, Niger

Progress/Results:
The results of experiments that capture the role of roots in groundnut, although not focused on root traits *per se* are reported here. 288 entries containing 268 cultivated entries of the reference collection and additional breeding lines were tested in a lysimetric system at ICRISAT, Patancheru in early 2009. The planting was done at same time as a parallel field planting in an Alfisol field. Two treatments were used, i.e. full irrigation and intermittent stress. The cylinders were sown on December 18th 2008 and plants grown under WW conditions until 35 DAS. The cylinders were saturated and allowed to drain for 2 days. Weighing was then performed approximately every week in the first month after stress imposition and then every two weeks afterwards and until maturity. The water losses in the WW treatment were compensated after weighing. Re-watering of the water stress treatment followed the same criteria of leaf wilting scoring used in the field. The scoring was as: 1-no wilting; 2-some wilting in some plants of the plot; 3-most plant of the plot are wilted; 4-some leaves in some plants show permanent wilting and scorching; 5-most plants of the plots have leaves reaching permanent wilting.

On average the pod yield was reduced by about 50% under water stress and there was a large range of variation between genotypes. There was a significant relationship between the pod yield under water stress obtained in the field and in the tube experiment. Pod weight decrease under water stress was concurrent to a decrease in seed number and 100-seed weight, indicating that both reproductive failure and grain filling failure occurred under intermittent stress in groundnut. Biomass dry weight was not significantly related to pod weight. Under these conditions, an assessment of TE was also performed, on long term basis (biomass and water used for transpiration assessed from 4 weeks after sowing until maturity). There was a large range of variation in TE, from 0.53 to 2.86 g kg-1 water transpired. These differences in TE explained up to 50% of the pod weight variation.

A multilinear regression analysis was performed where pod weight was taken as the dependent variable and T, TE and HI were taken as explanatory variables in an additive model with no interactions. The model explained 90% of the variation and each variable appeared to have a relatively equal weight on pod weight, all with a highly significant effect. Although further analysis of the data is needed, this result is the first of this kind, assessing both yield and yield components on same plants. It indicates very clearly that TE remains a valid selection criterion but that T and HI are equally important to achieve high yields and should be considered as selection criteria.
In the Rainy season 2009, a repeat of this assessment with 280 entries has been done in the lysimeters, using only a water stress treatment and using 20 entries only to assess pod yield under well watered conditions. The objective of this trial was to test which yield component trait would have the major effect on yield in a situation where a similar intermittent stress occurs during the rainy season, with lower temperature and higher air humidity.

Special Project Funding:
Tropical Legume Project

V Vadez, L Krishnamurthy, P Ratnakumar, HD Upadhyaya, RK Varshney and CLL Gowda

Sorghum mini-core (or reference) set screened for TE (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
375 accessions from the reference collection of sorghum, along with three controls were also screened for TE under water stress (WS) and well-watered (WW) conditions. Plants were grown in large pots (11" diameters, containing 11 kg of Alfisol). WS was imposed six-weeks after sowing to measure plant biomass before imposing drought. WS plants were exposed to progressive water stress by letting plant loose no more than 150 g per day during the first 4 days after imposing stress; no more than 100 g per day in the following 4 days; and no more than 75 g per days during the rest of the experiment. Since pots were weighed every 4 days only, this corresponded to a maximum water loss of 600 g over 4 days, 400 g in the subsequent 4 days, and then 300 g for any 4 day interval in the rest of the experiment. WW plants were maintained well-watered by re-adjusting pot weight close to field capacity on those days when the pots were weighed (every 4 days), and by adding water two days after weighing to bring back pots close to field capacity, based on transpiration data (from previous weighing intervals). All plants were harvested when the transpiration of the drought set fell below 10% of the transpiration of the well-watered set. Under WW condition, the CV of the TE measurement was 15% and TE (g biomass kg^{-1} water transpired) varied from 5.76 to 16.68. Under WW condition, the CV of the TE measurement was 22% and TE (g biomass kg^{-1} water transpired) varied from 7.08 to 23.62. The mean TE under well-watered conditions was 8.60 g biomass kg^{-1} water transpired and the mean TE under water stress was 11.73 g biomass kg^{-1} water transpired, about 50% higher.

Water uptake in sorghum: A set of 210 entries (152 reference set accessions + 58 marker-aided stay-green QTL introgressed lines) were assessed for water uptake under stressed conditions in lysimeters (2.0-m long and 25-cm diameter PVC cylinders), mimicking roughly the soil volume that sorghum plants would have at usual field planting densities. Two treatments were applied: a water stress treatment and a fully irrigated control. Preliminary analysis revealed wide variation in water extraction (10.2 kg plant^{-1} to 15.3 kg plant^{-1}) between the top

and bottom extractors under WS conditions. In WW conditions, the total water use varied from 10.5 kg to 42.3 kg of water per plant from 4 weeks after sowing until maturity. The ten highest water extractors under WS conditions were IS 2367, 5720, 23988, 20709, 929, 20351, 1127, 20387, 14259 and 3971 while the accessions that extracted lowest amount of water under similar conditions were IS 13848, 13452, 32234, 4821 18868, 33173, 28645, 30352, 30451 and SSM 547. In contrast, the accessions that extracted highest amount of water under WW conditions were IS 20842, 14529, 22506, 30443, 18922, 2205, 10978, 23903, 5720 and 5622, while the accessions that extracted lowest amount of water under similar conditions were IS 24009, 13452, 28645, 13848, 26731, 2398 and 12447 and 393 (411) 659, 452 (484) 510 and 651 (902) 656. These accessions belong to *bicolor, caudatum, durra, kafir, durra-bicolor, caudatum-bicolor, durra-caudatum,* and *guinea-caudatum* group of basic and intermediate races. IS 14259 and IS 18868 belonging to wild species *S. verticilliflorum*, while IS18922 to *S. drummondii*. Further, analysis of grain weight and its relation to water extraction is in progress.

The PVC experiment gave also the opportunity to assess TE across a fairly large range of genotypes, over a long period of time (from 4 weeks after sowing until maturity). TE value varied between 2.44 g kg^{-1} water transpired to 6.09 g kg^{-1} water transpired, and so showed a very large range of variation. A detailed analysis is needed to investigate how differences in TE relate to the presence or absence of certain staygreen QTL. In short, in S35 background, few staygreen QTL introgression lines had TE above S35. Introgression lines with Stg 3, Stg4 or Stg B had all fairly high TE equal or superior to S35. In R16 background, most Stg B, and Stg3 and few Stg4 introgression lines had high TE, equal or superior to R16. In any case, there were entries from the sorghum reference collection with TE higher than the highest of the staygreen trial entries.

Special Project Funding:
GCP Project Number: G4008.02 (SP1) Phenotyping sorghum reference set for drought tolerance

V Vadez, L Krishnamurthy, HD Upadhyaya, CT Hash and BVS Reddy

Output target 2011 2.3.4
Sorghum mini-core or reference set screened for root traits (2011)

Achievement of Output Target:
50%

Participating Countries:
Australia, India

Participating Partners:
University of Queensland, Directorate of Sorghum Research

Progress/Results:
Root traits as such are no longer the direct focus of the crop physiology laboratory, which now focus on root functionality.

Special Project Funding:
ACIAR

V Vadez, L Krishnamurthy, HD Upadhyaya and CLL Gowda

Mini core collection of groundnut evaluated for resistance to seed infection by *Aspergillus flavus* and aflatoxin contamination (2009)

Achievement of Output Target:
50%
During 2006-07 post rainy season, the field harvest seed was not sufficient to further carryout the laboratory experiments. And in 2007-08 post rainy season, since the harvested seed was sent to ICRISAT-Naimy center for further evaluation, again laboratory experiments were not conducted. Only in 2008-09 post rainy season, the experiment was fully conducted and multi-season data analysis is in progress.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
A total of 184 groundnut mini core collection accessions along with 4 productivity controls and two susceptible controls for aflotoxin resistance (JL-24 and J-11) were evaluated in three replications since 2006-07 post rainy season for their resistance to seed infection by *Aspergillus flavus* and subsequent aflatoxin contamination. We started with artificial screening in the lab using 40-50 seed of the each genotype and remaining 40 seeds were planted in one row for each genotype. Since the field harvest seed was not sufficient for seed plating, aflatoxin analysis and planting for next season, we could not do any analysis in the lab for the field harvested trial. In the next season (2007-08 post rainy) the 188 lines in three replications was planted and harvested in May 2008. Due to insufficient seed quantity for laboratory analysis for A. flavus seed infection and aflatoxin contamination the analysis could not be continued; the 184 mini core lines were planted for third year during the 2008-09 post rainy season, it was harvested in May 2009, and the material was analyzed for *A. flavus* infection and aflatoxin contamination.

Special Project Funding:
NA

H Sudini and HD Upadhyaya

Groundnut and pigeonpea mini core collections salinity evaluation data analyzed (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pigeonpea: We found that a NaCl treatment of 1.01 g kg^{-1} Alfisol was suitable to salinity screening in pigeonpea. Using that treatment, we found large variation in the SSI and the RR% in both cultivated and wild accessions. The amount of Na accumulation in shoot showed that more tolerant materials accumulated less Na in shoot except the wild species following an utterly paradoxical pattern i.e. positive and significant correlation between the root biomass and Na^{+} accumulation than cultivars.

Overall, we found that wild species *C. acutifolius, C.cajanifolius* and *C.lineata* were mostly sensitive, whereas *C. platycarpus, C. scaraboides* and *C. sericea* provided good sources of tolerance. It was interesting to notice that *C. scaraboides* also provided a wide range of sensitive materials. Although we would have expected that accessions originating from putative saline areas would provide higher levels of tolerance, the minicore collection of pigeonpea provided a wide range of variation in the salinity response. It should be noted that, either from the minicore collections, or the set of accessions from putatively salinity affected areas, there was a large number of tolerant accessions originating from Bangladesh.

Groundnut: Groundnut demand is increasing in countries like India, where saline land could be put under groundnut cultivation. The objective of this study was to identify groundnut genotypes fro mini core collection and having salinity tolerance for their use in breeding. A total of 275 genotypes of groundnut including genotypes from putatively salinity affected areas were screened across three different seasons for shoot biomass and seed yield, under saline and non-saline conditions. Shoot biomass under saline conditions showed limited genotypic variation and was not kept as a selection criterion. In comparison, a six-fold range of variation for pod yield under salinity (10-12.5 dSm^{-1} NaCl) was observed. Pod yield under saline and non-saline conditions were poorly related. Although the genotypic variation for pod yield under saline conditions was large, it also showed large G×E interaction. We report a set of 14 tolerant and 17 sensitive genotypes, consistently contrasting across years for pod and seed yield and pod and seed numbers under saline conditions across seasons, and those could be used in breeding. Our attempt to increase the frequency of tolerant lines by selecting landraces from putatively salinity affected area was not successful and the mini-core set of germplasm provided most of the salinity tolerant entries.

Special Project Funding:
NA

V Vadez, L Krishnamurthy, HD Upadhyaya and RK Varshney

Reference sets of chickpea, pigeonpea, and groundnut evaluated for salinity tolerance (2010)

Achievement of Output Target:
100% for chickpea
50% for groundnut and pigeonpea

Participating Countries:
India, Australia

Participating Partners:
University of Western Australia, Punjab Agricultural University

Progress/Results:
The reference set of chickpea was assessed in 2007-08 (reported in Archival 2008) and 2008-09. The trial in 2008-09 was largely a failure because of severe stress in the Alfisol that was used and then heavy wilt effect on salinity affected plants. The data of 2007-08 are part of a paper that is about to be submitted.

Regarding groundnut and pigeonpea, lack of funding has impeded the assessment of the reference collections for that stress.

Special Project Funding:
ARC-Linkage grant, COGGO, Challenge Program W&F

V Vadez, L Krishnamurthy, HD Upadhyaya and RK Varshney

C ^{13} in chickpea analyzed at JIRCAS (Annual)

Achievement of Output Target:
100%

Participating Countries:
India and Japan

Participating Partners:
JIRCAS, UAS Bangalore, ICRISAT

Progress/Results:
To build further on this work, 280 accessions of the chickpea reference collection were planted in the field at Patancheru during 2008-09 season. Data on the phenology, yield and yield components were collected and the samples were analyzed for delta carbon. However, the trial that was conducted at UAS, Bangalore was not that successful due to late sowing and this trial is being repeated during the 2009-10 season. Required observations on SLA, SCMR and delta carbon are being generated at both the locations. However the harvests expected to be completed by the end of Feb 2010.

L Krishnamurthy, RK Varshney, PM Gaur and HD Upadhyaya

Ten chickpea lines identified, which showed steady high water use efficiency (WUE) as well as high yield in two locations (2009)

Achievement of Output Target:
100%

Participating Countries:
India and Japan

Participating Partners:
JIRCAS, IIPR Kanpur, ICRISAT

Progress/Results:
As already reported in 2008, chickpea mini core collection (211 accessions) and 5 control cultivars were evaluated for variation in the SPAD Chlorophyll Meter Reading (SCMR), a surrogate trait for Water Use Efficiency (WUE), during 2005-06 and 2006-07 postrainy seasons. Based upon the two years' results, 20 top ranking germplasm accessions were identified in each season and five accessions were the best common entries. These were ICC 1422, ICC 4958, ICC 10945, ICC 16374 and ICC 16903.

L Krishnamurthy, V Vadez and HD Upadhyaya

Output target 2.3.6 Reference sets evaluated and genotyped for enhanced utilization (2011)

Chickpea reference set phenotyped for root traits in PVC cylinders (120cm height) (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Two hundred and ninety one cultivated accessions of the reference collection along with five controls had been evaluated again for root traits in the cylinder culture system. The experiment was sown in Oct 2008 and harvested in Nov 2008 in an alpha lattice with three replications. The rooting depth, root dry weight, root volume, root surface area and the root length density were the root-related data collected along with the shoot dry weight of two plants from each cylinder. There were large and significant variations among the reference collection for all the traits that were recoded (Figure 3). Though significant, the variation observed for maximum rooting depth was relatively narrow. There was a close association of the root traits ($r^2=0.27^{***}$ for root dry weights and $r^2=0.14^{***}$ for root length densities) across the two seasons of the study showing that these consistent across seasons.
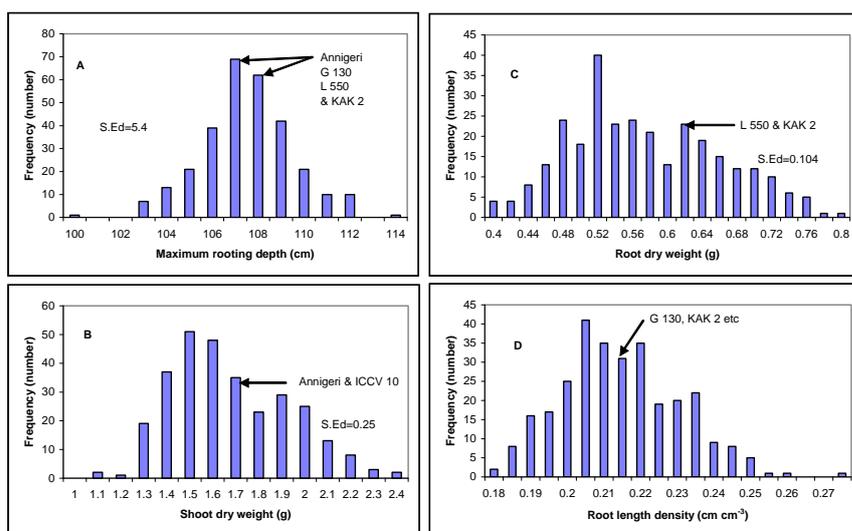

Fig 1. Range of variation for (A) maximum rooting depth, (B) shoot dry weight (g), (C) root dry weight (g) and (D) root length density in the chickpea reference collection. Data are BLUPs recorded during the postrainy season 2008-09.

N Lalitha L Krishnamurthy, HD Upadhyaya RK Varshney, and PM Gaur

Chickpea reference set genotyped with 100 SSR markers (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
We screened 350 SSR markers on two diverse chickpea germplasm (ICCV 2 and Annigeri), and identified 100 most polymorphic markers to generate additional data points on chickpea reference set (300 accessions). Genotyped 300 accessions with 100 SSRs using, ABI3130xl automatic DNA sequencer (PE- Applied Biosystems, Foster City, California). The electrophoretic data were exported to the Genescan 3.1 software (PE- Applied Biosystems, Foster City, California) to size peak patterns, using the internal LIZ-500 size standard and GENOTYPER 3.1 (PE- Applied Biosystems, Foster City, California) for allele calling. The allelic data obtained for the entire marker sets were subjected to AlleloBin programme for binning raw data and allele calling based on the repeat units of SSR motif for the corresponding marker. Data validation and analysis is in progress.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, N Lalitha, RK Varshney, A Rathore and L Krishnamurthy</div>

Groundnut reference set phenotyped for traits associated with drought resistance (TE & roots) (2009)

Achievement of Output Target:
100%

Participating Countries:
India, Niger

Participating Partners:
ICRISAT Patancheru, ICRISAT Niger

Special Project Funding:
NA

Progress/Results:
Assessment of the reference collection in the field (Niger and India): 288 entries containing 268 cultivated entries of the reference collection and additional breeding lines were tested in an Alfisol precision field (homogenous depth) in 2008-09 at ICRISAT, Patancheru in India. Out of these, 246 common entries have been tested in a sandy soil in Niger at the ICRISAT Sahelian center (in a trial with 268 entries) in late 2008 (late planting in the rainy season) and early 2009 (summer season). Trials were Alpha lattice with 3 replications in India (2 row plot, 4-m rows) and 6 replications in Niger (2 row plots, 2-m long). The reason to increase the replication number in Niger was because of the higher variability in the field. In both trials, two treatments were used (fully irrigated and intermittent stress). The fully irrigated treatment received irrigation approximately every 5-10 days depending on ET and location-dependent water application (30mm in Niger or 50 mm in India) irrigation each time. In both trials, an intermittent stress was applied from about flowering time (35 days after sowing in Niger, about 45 DAS in India, flowering delay due to cool season at time of planting) until maturity. It consisted roughly in skipping one irrigation in two of the irrigated treatment. At irrigation of water stress treatment, 30 (Niger) or 50 (India) mm of water was applied. The decision to irrigate the water stress treatment depended on an agreed scoring of leaf wilting of the plots. The scoring were such as: 1-no wilting; 2-some wilting in some plants of the plot; 3-most plant of the plot are wilted; 4-some leaves in some plants show permanent wilting and scorching; 5-most plants of the plots have leaves reaching permanent wilting. This protocol has been detailed and distributed to all partners of the groundnut objectives involved in drought screening in the field.

The Table 16 indicates a very large variation for pod weight (g/m^2) under stress conditions in both sites. The pod weight reduction was about 50% in India, 60% in Niger in the late rainy season and about 75% in Niger during the summer season. This later trial was carried out to test the possibility of an interaction between temperature and water stress. The analysis of data will be completed once we have the data for trials of 2009 and early 2010. However, it is clear that pod set was affected by the high temperature of the summer in Niger in some of the genotypes. The haulm weight was reduced about 25% in India and 40% in Niger (regardless of season), which shows that vegetative development did not appear to be affected by summer temperature.

In India, the pod weight under stress was closely related to the pod weight under fully irrigated conditions (r^2=0.45) and an index of tolerance has been computed to remove the component of yield potential out of the seed yield under stress. Such relationships were weak in the late planting of 2008 in Niger (R2=0.08) and relatively stronger in the summer season (R^2 = 0.18). The harvest index declined under stress conditions, especially in the summer trial where there is a combination of drought and heat stress. The harvest index varied largely among genotypes, indicating the need to target some research in groundnut toward the reproductive stage sensitivity to water stress.
The trial also revealed that the popular lines tested had poor pod yield under stress conditions (e.g. JL24 and ICGVSM87003) in the trial in India. Likewise, there were 30 lines with higher pod yield under stress than Fleur 11 and 55-437, varieties popular to WCA and known to be drought tolerant. So, these results show that there is a good scope to improve the drought tolerance of popular entries in Sub-Saharan Africa. In addition, we were surprised to find a significant relationship between the pod yield under stress in Niger and that in India (using the entries common to both trials) (R^2 = 0.16), since the environmental and soil conditions were radically different. We attribute that relationship to the standard protocol that has been used across locations to apply an intermittent stress. This is an encouraging result that might allow us to select contrasting entries for the development of new breeding populations that would be useful across environments. These trials are being repeated in Niger and will soon be planted in India (Dec 09). The added value of the trial carried out in Niger is the

systematic aflatoxin contamination that we have been measuring in seed samples, and that reveal a large range of variation. There also, it gives the possibility to develop populations that also contrast for aflatoxin contamination and opens new opportunities for an issue that is extremely important in groundnut, especially with a view towards MARS (= multi-trait breeding) in groundnut. In addition, it provides good material to start investigating the interactions between aflatoxin contamination and sensitivity to drought.

Table 16. Range and means of haulm weight, pod weight and harvest index in groundnut reference set.

	Well Watered			**Water stress**		
	Haulm Wt	**Pod Wt**	**HI**	**Haulm Wt**	**PodWt**	**HI**
			India			
Mean	768	406	0.35	587	216	0.28
min	217	79	0.10	86	39	0.10
max	1308	746	0.58	960	406	0.49
	Niger - Late rainy season 2008					
Mean	453	281	0.38	261	110	0.30
min	198	118	0.25	105	0	0.00
max	778	477	0.51	413	171	0.49
	Niger - Summer 09					
Mean	1143	306	0.23	719	79	0.11
min	418	104	0.04	222	26	0.04
max	8185	500	0.43	3033	168	0.25

V Vadez, F Hamidou, HD Upadhyaya and RK Varshney

Assessment of the reference set for TE: TE was assessed in the reference set in Feb-Mar 09 in India, using the standard protocol to assess TE and 2 treatments (WW and WS). This trial was conducted under high VPD conditions and was a repeat of the 2007-08 trial under low VPD conditions. The trial mean was 2.14 g kg^{-1} water, lower than the 2.39 g kg^{-1} water of the previous trial, due to higher VPD conditions. The range of variation for TE was also very large (1.50 – 2.92g kg^{-1} water) and the CV of the trial was very good for such measurement and that range of variation (CV = 15%). The TE value under WW conditions were significantly related to those obtained in 2007-08, despite the large GxE interaction explained by the large differences in the VPD conditions. These data indicate that we will be able to identify genotypes with large TE differences. Because of the large GxE interaction, there is very likely genotypic variation for the k component in peanut (TE = k/VPD). The variation in the k component is obviously a cardinal finding in the area of water use efficiency, since "k" is considered to be constant for each crop species. So, the selection of genotypes for TE should ensure that those lines are selected which are capable of maintaining high TE across VPD conditions. For instance, genotypes ICG 11386 and ICGV 02022 were found with high TE under WW conditions in similar assessment made in Niger. Among the well-known breeding materials, ICGS76 achieved high TE (2.60 g kg^{-1} water), whereas JL24 and TAG24 were among the lowest (as previously found). Under water stress the trial mean was slightly higher than under WW (2.42 g kg^{-1} water) and a wide range of variation from 1.58 to 3.37 g kg^{-1} water and a good quality of experimental data (cv = 17%) for such a difficult measurement.

We have also investigated the relationships between TE and possible explanatory traits related to conductance and mesophyll efficiency. We found a highly significant relationship between TE and the canopy conductance (a proxy for stomatal conductance), showing that part of the TE differences was explained by differences in the control of stomata. This is an important and groundbreaking result since the prevailing idea in groundnut is the absence of contribution of stomata regulation on TE. This confirms well similar data in RIL populations and other data with transgenics (Devi et al., forthcoming). We found also a positive relationship with dry weight, which can be taken as a proxy for photosynthesis.

V Vadez, HD Upadhyaya and RK Varshney

Groundnut reference set genotyped with 100 SSR markers (2010)
Achievement of Output Target:
40%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
A reference set of groundnut was planted during 2009-10 postrainy season. Leaf samples from 20 days old seedlings were collected to extract the DNA for genotyping groundnut reference set. A set of 100 SSR markers were chosen from the genetic linkage map of groundnut. The markers were chosen based on two criteria (1) whole genome coverage and (2) uniform distribution on all linkage groups groundnut. In parallel, the reference set has been genotyped with a set of 15360 DArT markers. As a result 3184 and 4553 markers were found polymorphic on cultivated and wild genotypes respectively.

Special Project Funding:
NA

HD Upadhyaya and RK Varshney

Candidate gene diversity analyzed in chickpea reference set (300 accessions) for drought tolerant alleles (2010)

Achievement of Output Target:
100%

Participating Countries:
France, India

Participating Partners:
CIRAD, Osmania University and ICRISAT

Progress/Results:
Progress/Results: In order to isolate probable candidate genes involved in drought tolerance, extensive bibliographic survey was made and candidate genes are identified, which might have role in drought tolerance across the plants. ICRISAT was one of the Ortholabs involved in identifying the ortho/homolog sequences in DREB2A in seven targeted species (chickpea, common bean, barley, sorghum, rice, potato and cassava) under the framework of GCP sponsored "Allelic Diversity on Orthologous Candidate Genes" project. Attempts were made to isolate DREB2 homologs from the mentioned species using phylogeny based degenerate primer approach and by using specific primers for the corresponding genes. As a result, isolation of DREB2 genes was successful in chickpea, common bean, rice, sorghum and barley (Nayak et al. 2009). DREB2A promoter was also isolated in chickpea in order to identify the allelic diversity at the regulatory region. Subsequently a set of eight diverse genotypes of the reference collection was sequenced at these candidate orthologous sequences.

Eight diverse accessions (Annigeri, ICCV 2, ICC 4958, ICC 283, ICC 8261, IC 10029, ICC 1882 and ICC 4411) from chickpea reference set were sequenced at CAP2 gene (homolog of DREB2A) and its promoter. Apart from the DREB2A isolation in five crop species, efforts were made to identify the other candidate genes like sucrose synthase (SuSy), sucrose phosphate synthase (SPS), abscisic acid stress and ripening gene (ASR) in chickpea using heterologous primers designed from Medicago. Eventually putative SuSy, SPS and ASR have been isolated successfully in eight diverse genotypes of chickpea at ICRISAT. Other collaborative partners of ADOC project identified putative homolog of ERECTA in chickpea. The candidate genes conferring drought tolerance were sequenced in 300 accessions of reference set of chickpea. The results of which are explained in output target 2.4.7.

Special Project Funding:
GCP

<div align="right">RK Varshney, S Nayak, B Jayashree, HD Upadhyaya,
CLL Gowda and DA Hoisington</div>

Output target 2011 2.3.2
Diversity analyzed for the molecular markers and markers associated with drought related (root traits) in chickpea identified (2011)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Special Project Funding:
NA

Progress/Results:
We screened 350 SSR markers (Huttel et al., 1999 and Winter et al., 1999) on two diverse chickpea genotypes (Annigeri and ICCV2). A total of 195 primer pairs produced scorable amplicons on the two chickpea genotypes. Of these123 most prominent markers were molecularly profiled on 300 accessions (Cultivated – 297 and wild – 7) of chickpea reference set. Data quality was checked and two markers CaSTMS20 and CaSTMS28 were excluded from analysis as these markers were monomorphic. We analysed 121 SSR data on 300 accessions with 3% missing data. Data was analysed using Power Marker V3.25 and DARwin 5.0.156 by using the Allelo binned data.
 A total of 1657 alleles were detected in the reference accession. Number of alleles ranged from 2 to 30 with an average of 13.5 alleles per marker. Highest numbers of alleles (30) were detected in TS62, whereas CaSTMS23 produced minimum number of (2) alleles. Cultivated type captured 1651 (99% of entire reference set) alleles and the wild types captured 761(46%) alleles. Desi types (197 accessions) captured 1608 (97% of cultivated accessions) alleles, kabuli type (86 accessions) captured 1521(92%) alleles, and peas-shaped (10 accessions) captured 955 (58%) alleles. Cultivated contributed 155 unique alleles (Desi-113, kabuli -37, pea – 5) and Wild type contributed 6 unique alleles. The gene diversity ranged from 0.1594 to 0.9497 with an average of 0.7874. The PIC value ranged from 0.15 to 0.95 with an average of 0.76. Although TS62 gave maximum number of alleles i.e. 30, its PIC value (0.93) was found to be less than TA110 (PIC value 0.94) which had 18 alleles. Heterozygosity ranged from 0.0034 to 1.000 with an average of 0.5570.

<div align="right">HD Upadhyaya, N Lalitha, RK Varshney, A Rathore,
V Vadez and L Krishnamurthy</div>

Markers associated with drought related (root traits) in chickpea identified: Chickpea reference was phenotyped for drought related traits like Shoot Dry Weight- Shoot DW (g), Rooting Depth- RDp (cm), Root Dry Weight- RDW (g), RDW / Total Dry Weight Ratio (=Shoot DW+RDW)- R-T Ratio (%),Root Dry Weight- RL (cm), Root Length Density- RLD (cm cm-3), Root Surface Area- RSA (cm2), Root Volume- RV (cm3). Association mapping using the molecular data on 121 SSR markers and phenotypic data is in progress.

<div align="right">HD Upadhyaya, N Lalitha, RK Varshney,
A Rathore,V Vadez and L Krishnamurthy</div>

Output target 2011 2.3.7 Germplasm sets evaluated for utilization in Africa

Promising and adaptable materials identified and distributed and evaluated in regional finger millet trials the ESA (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Special Project Funding:
NA

Progress/Results:
There are increasing requests for finger millet blast resistant varieties for evaluation by collaborators across the finger millet production areas and countries. The objective is to make available to farmers some of the identified blast resistant materials to enhance productivity and meet the growing demands for food and nutrition security as well as market needs. A regional finger millet trial with 25 elite and blast tolerant/resistant lines was constituted and sets were sent to Uganda, Kenya and Tanzania. A finger millet mini core collection of 70 lines and control cultivars was evaluated for agronomic traits and reaction to stress environment (blast in Uganda, striga in Kenya and drought in Tanzania). In each country 15 lines were selected for evaluation under farmers' fields through PVS and farmer contribution in identification of elite lines. On farm evaluation was done in Tanzania and field days were conducted in September at Maruku ARI and attended by 33 farmers and extension officers. A finger millet brochure was developed and translated into Swahili to provide basic information on aspects of production, varieties and the crop. Farmers selected their preferred varieties form the set of 15 as well as from the regional trial. The selected lines are IE 2440, IE4816, GB 033439, IE6421 and IE3952. From the regional finger millet trials the lines KNE758 and KNE648 and Acc 32 and Acc14 were identified as best lines and these varieties produced grain yields of 1.2-2.3t ha^{-1}. The identified varieties will be further evaluated on farm and in the regional finger millet trials across the 4 finger millet target countries.

M Mgonja, H Ojulong, J Kibuka, E Manyas and P Sheunda

Finger millet collection gaps were identified in Kenya, Uganda and Tanzania. Database for sorghum collection including passport data was acquired from ICRISAT India. The NARS partners were contacted to verify whether there are additional collections that were done and information has not been mailed to ICRISAT. Tanzania and Kenya curators provided additional datasets of 275 and 1908 respectively. The Uganda database had 127 out of 820 accessions not geo-referenced. For those accessions that had village names, GIS experts were consulted and they determined village geo-references. The other limitation for this data base was that most of the geo-references provided were for the multiplication sites and did not reflect the site where the materials were collected. The GIS unit at ICRAF was consulted and mapped all the available collections. Partners in the NARS, who have local knowledge of finger millet producing areas, were consulted to assist in identifying collection gaps in their respective countries. Evidence of collection gaps in Kenya, Uganda and Tanzania provide opportunity for targeted collection to fill gaps and this will help enrich the finger millet crop diversity and enhance its crop improvement. The remaining tasks are to conduct collection trips in the targeted areas and this will be done under the HOPE project milestones

MA Mgonja, H Ojulong and E Manyasa, P Sheunda and Kibuka

African accessions of pearl millet reference collection characterized in West Africa (2011)

Achievement of Output Target:
75%
The multi-location characterization trails have been successfully conducted. Data analysis and data preparation for ICRISAT data base are currently underway.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
A multi-location trial consisting of 74 accessions (those with enough seed) and 7 controls was prepared for evaluation under low-input and fertilized conditions (2 reps each) at LCRI-Maiduguri (Nigeria), IER-Cinzana (Mali), and at ICRISAT-Sadore (Niger). In addition, all 81 regenerated accessions were evaluated with 18 controls at ICRISAT-Sadore for Striga resistance in four replications. The Sadore trials were uniform and should provide good data. Data entry is still underway. The partner trials in Nigeria and Mali were visited during the rainy season. Due to religious clashes and subsequent drought, the Maiduguri trial had been planted late on 3rd August 2009. But due to some late rains in October, the LCRI has been able to harvest most of the entries. The Cinzana trial was well managed and close to maturity during the time of the visit on 19th October. High downy mildew pressure and many empty heads (sign of non-adaptation – too early materials) were observed. Otherwise the evaluation field was very uniform, and good data are expected from this site. Data entry is still underway. Partner's data are expected in early January 2010 and must be put into the ICRIS data base until May 2010.

Special Project Funding:
NA

BIG Haussmann

Diversity for micronutrients contents in a sorghum core collection from at least 2 ABS target countries established (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
The African Biofortified Sorghum (ABS) project is targeting 5 countries namely Kenya, South Africa, Nigeria, Burkina Faso and Egypt. A core collection of sorghum germplasm from these countries was constituted and morphological characterisation was done in 2006 and 2007. Data from 426 sorghum accessions collected from ABS target countries and sent to ICRISAT-India for iron and zinc content analysis was received. Iron content ranged from 20.5 ppm in IS 7455 to 108.5 ppm in IS 18896 with a mean of 40.9 ± 9.4. Zinc content was from 7.7 ppm to 44.5 ppm in IS 21340 and IS 18896 respectively (mean 17.2 ± 3.8). Analysis of variance showed country of origin not significant for iron, though accessions from Kenya had highest averages of 42.27 and Egypt the lowest of 38.45. Zinc was significant (P=0.021) for country of origin with accessions from Egypt with the highest mean (19.36 ppm) and those from Burkina Faso the lowest (16.31 ppm). Simple correlations revealed iron to be positively correlated to plant height, percentage shattering, zinc content, number of panicles per plant, panicle length and negatively correlated to panicle shape. Zinc on the other hand was not correlated to any trait except zinc content. The high positive correlation (0.61) between zinc and Iron means they can be improved concurrently. A number of crosses have been initiated to understand the genetics of Fe and zinc and to enhance iron contents in some preferred varieties.

Special Project Funding:
NA

H Ojulong, M Mgonja, E Manyasa, P Sheunda and J Kibuka

Wild Arachis evaluated for target traits (GRD, ELS, aflatoxin resistance) at hotspot locations in ESA (2010)

Achievement of Output Target:
No activity this year

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Not reported for 2009

Special Project Funding:
NA

Gene introgression carried out for foliar and viral disease resistance from wild *Arachis* germplasm into cultivated varieties (2011)

Achievement of Output Target:
50%

Participating Countries:
Malawi

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi

Progress/Results:
Five accessions from the A. Hypogaea x A. Cardenasii *with* very high levels of resistance to *ELS* from the species cardenasii were identified. These included the following accession numbers: 4366-2, 4366-5, 4531-7, 2928, and 2929-4. These accessions had the same level of resistance as the best available ELS resistant elite lines in the program such as ICGV-SM 95741; however most of them had relatively fewer numbers of pods per plant. These could be useful sources of resistance to ELS though it may take some more time before this resistance is deployed into a good agronomic background.

Special Project Funding:
NA

ES Monyo, N Mallikarjuna and HD Upadhyaya

Output 2.4: Genetic diversity and population structure of staple crops and small millets assessed and mapping populations, RILs developed and DNA extracts assembled, conserved and distributed and new knowledge and knowledge shared with partners

Summary: Genotyping datasets for groundnut, pigeonpea, pearl millet, finger millet and foxtail millet composite collections have been made available globally via the internet, http://www.generationcp.org/ . Genetic structure, diversity and allelic richness in a composite collection of chickpea, using SSR markers was published.

Regenerated seeds of trait specific (morphological, nutritional and stress resistance) germplasm in chickpea, pigeonpea, groundnut, pearl millet, sorghum, finger millet and foxtail millet were made available to partners on request under SMTA.

DNA extracts of the reference sets of chickpea, pigeonpea, groundnut, sorghum and finger millet have been conserved and supplied to CIRAD on request.

Advanced generation interspecific derivatives of A. *hypogaea X A. chiquitana and A. hypogaea X kretschmeri* have been derived and hybrids between natural and synthetic tetraplods of groundnut were generated.

Drought responsive candidate genes such as CAP@ and promoter, SuSy, SPS, ASR and ERECTA have been identified and sequenced on the chickpea reference set of 300 accessions.

An integrated genetic map of an intraspecific cross of chickpea was published and that of an interspecific cross has been developed. A new set of modules for diversity analysis, format parsing and data manipulation with PISE wrappers was published.

A total of 12 agriculturally beneficial micro-organisms (7 bacteria and 5 actinomycetes) were identified by 16s rDNA gene sequence analysis and submitted to NBAIM.

Output target 2010 2.4.1 Genetic diversity and population structure of staple crops assessed

Diversity assessment of chickpea published (2009)

Achievement of Output Target:
100%

Participating Countries:
India, Syria

Participating Partners:
ICRISAT and ICARDA

Progress/Results:
An extensive characterization of PGR provides an opportunity to dissect structure, mine allelic variations, and identify diverse accessions for crop improvement. We assessed the genetic structure, diversity and allelic richness in a composite collection of chickpea (3000 accessions), using 48 SSR markers, and established a reference set of 300 accessions. The 48 SSR markers detected 1683 alleles in 2915 accessions, of which, 935 were considered rare, 720 common and 28 most frequent. The alleles per locus ranged from 14 to 67, averaged 35, and the polymorphic information content was from 0.467 to 0.974, averaged 0.854. Marker polymorphism varied between groups of accessions in the composite collection and reference set. A number of group-specific alleles were detected: 104 in Kabuli, 297 in desi, and 69 in wild *Cicer*; 114 each in Mediterranean and West Asia (WA), 117 in South and South East Asia (SSEA), and 10 in African region accessions. Desi and kabuli shared 436 alleles, while wild *Cicer* shared 17 and 16 alleles with desi and kabuli, respectively. The accessions from SSEA and WA shared 74 alleles, while those from Mediterranean 38 and 33 alleles with WA and SSEA, respectively. Desi chickpea contained a higher proportion of rare alleles (53%) than kabuli (46%), while wild *Cicer* accessions were devoid of rare alleles. A genotype-based reference set captured 1315 (78%) of the 1683 composite collection alleles of which 463 were rare, 826 common, and 26 the most frequent alleles. The neighbour-joining tree diagram of this reference set represents diversity from all directions of the tree diagram of the composite collection. The genotype-based reference set, reported here, is an ideal set of germplasm for allele mining, association genetics, mapping and cloning gene(s), and in applied breeding for the development of broad-based elite breeding lines/cultivars with superior yield and enhanced adaptation to diverse environments. A journal article published in BMC Biology.

Special Project Funding:
GCP: Genotyping chickpea composite collection

<div align="right">HD Upadhyaya, SL Dwivedi, M Baum, RK Varshney,
SM Udupa, CLL Gowda and DA Hoisington</div>

Diversity assessment of sorghum published (2010)

Achievement of Output Target:
No report provided

Output target 2010 2.4.2
Datasets for groundnut and pigeonpea composite collections genotyping made available globally via the internet (2010)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Datasets for groundnut (1000 accessions with 21 SSR) and pigeonpea (1000 accessions with 20 SSR) composite collection made available globally via the internet on http://www.generationcp.org/
The mechanism to make this data public is also available currently via ICRIS on the internet.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, RK Varshney, S Senthilvel, T Shah and CLL Gowda</div>

Diversity and population structure of pearl millet composite collection analyzed and reference set (300 accessions) established (2010)

Achievement of Output Target:
80%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pearl millet composite collection (1021 accessions) was genotyped using 19 SSR loci spread across seven linkage groups of pearl millet to study genetic diversity and population structure and from it select a reference set of 300 most diverse accessions. The composite collection accessions were highly heterogeneous and up to 8 alleles were detected per locus. A total of 230 alleles were detected, of which, 102 were rare alleles (1%). Only seven alleles were unique in wild species whereas 30 in landraces. The clustering pattern indicated that the accessions were largely grouped by geographically but not by biological status. The released cultivars and breeding materials were scattered across different clusters. A reference set of 300 accessions was chosen using 'Max length sub tree' option of DARwin 5.0 based on Euclidean distance matrix derived from allele frequency values. The reference set has captured 94.8 per cent of the composite collection alleles (230). This reference set will be profiled with additional markers and extensively phenotyped for traits of economic importance to identify accessions with beneficial traits for utilization in pearl millet breeding and genomics.

Special Project Funding:
NA

<div align="right">

HD Upadhyaya, S Senthilvel, RK Varshney, CT Hash,
CLL Gowda, A Rathore and T Shah

</div>

Diversity assessment of pearl millet published (2011)

Achievement of Output Target:
25%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Pearl millet composite collection of 1021 accessions and 19 SSR markers was assessed and data is being processed for genetic diversity assessment.

Special Project Funding:
NA

<div align="right">

HD Upadhyaya, S Senthilvel, RK Varshney, CLL Gowda,
DV Yadav, CT Hash, A Rathore and T Shah

</div>

Data sets for pearl millet, finger millet, and foxtail millet composite sets made available globally via Internet (2010)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Datasets for pearl millet (1021 accessions with 19 SSR), finger millet (1000 accessions with 20 SSR), and foxtail millet (500 accessions with 19 SSR) composite collection made available globally via the internet on http://www.generationcp.org/

Special Project Funding:
NA

<div align="right">

HD Upadhyaya, A Bharthi, RK Varshney, S Senthilvel,
CLL Gowda and T Shah

</div>

The diversity of the sources of resistance to the groundnut rosette virus in groundnut assessed and documented (2009)

Achievement of Output Target:
75%
There was an outbreak of red spider mites in the glasshouses which masked the symptoms. The study will be repeated 2009/10 to confirm the observations

Participating Countries:
Malawi

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi

Progress/Results:
In order to confirm the diversity of the sources of resistance to GRD and viral transmission in some of the known resistance sources, grafting experiments were conducted at Chitedze Research Station, Malawi in glass houses. Two experiments were conducted. a) test plants used as root stock with the susceptible check JL 24 used as a scion. b) the second set, test plants used as scions with the susceptible check JL 24 used as a rootstock. There was an outbreak of red spider mites in the glasshouses which masked the symptoms. The study will be repeated 2009/10 to confirm the observations.

Eighty five percent (85%) of test plants used as scions developed serious chlorotic rosette symptoms within 60 days as compared to 9 % of the same but used as root stock. Susceptible checks did not perform differently whether as a scion or rootstock all succumbed to rosette. The following viral transmission differentials were observed: whether used as scions or rootstocks RG 1, ICGV-SM 03701, ICGV-SM 01710, ICGV-SM 01706, ICG 14705 presented a resistance reaction. ICGV-SM 01703, ICGV-SM 01705, ICGV-SM 01708, ICGV-SM 03702, ICGV-SM 03703, ICGV-SM 03708 and ICG 6888 presented a resistance reaction when used as rootstocks but susceptible reaction when used as scions. This observed diversity in viral transmission between the lines which needs to be confirmed in the absence of the masking symptoms of red spider mite attack could have implications on the diversity of sources of resistance to the groundnut rosette virus.

Special Project Funding:
NA

<div align="right">ES Monyo, E Sichone-Chilumpha and W Munthali</div>

Output target 2010 2.4.2 Reference sets of small millets germplasm established

Output target 2009 2.4.1 Genetic diversity and population structure of finger millet composite collection assessed and reference set (300 accessions) established (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Finger Millet: Genotyped composite collections of finger millet (1000 accessions) with 20 SSR markers. After data validation 20 SSR loci data on 959 accessions were analyzed. This composite collection showed rich allelic diversity (231 alleles, 11.6 alleles per locus, 121 common alleles and 110 rare alleles at 1%), group-specific unique alleles, and common alleles sharing between the races and geographical groups. Markers UGEP 81, UGEP 10, UGEP 102, UGEP 26, and UGEP 77 detected the large number of alleles (10-21). Unique alleles are those detected in a group of accessions but absent in other groups. Race-specific unique alleles were 37 in Vulgaris, 5 in Plana, 4 in Africana, and 2 in Compacta while region-specific alleles were 29 in the accessions originating from East Africa, 12 in the accessions originating from South Asia, 11 from Southern Africa, and one each in Central Africa and Europe. The common alleles shared by two groups were 15 for East Africa and South Asia, 5 for East Africa and Southern Africa, and 3 for South Asia and Southern Africa. A reference set consisting of 300 genetically most diverse accessions have been formed. This reference set captured 206 (89.2%) of the 231 composite collection alleles, representing diversity from the entire spectrum of composite collection. Ph D thesis of Ms A. Bharthi is under review.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, A Bharthi, CLL Gowda, S Senthilvel, RK Varshney,
CT Hash, DA Hoisington, A Rathore and T Shah</div>

Output target 2010 2.4.3 Genetic diversity and population structure of foxtail millet composite collection assessed and reference set (200 accessions) established

Achievement of Output Target:
75%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Foxtail Millet: Genotyped composite collections of foxtail millet (500 accessions) with 20 SSR markers. After data validation 19 SSR loci data on 452 accessions were analyzed. This composite collection showed rich allelic diversity (362 alleles, 19.1 alleles per locus, 196 common alleles and 166 rare alleles at 1%), group-specific unique alleles, and common alleles sharing between the races and geographical groups. Markers UGEP53, UGEP81, UGEP15, UGEP90, and UGEP33 detected large number of alleles (28-35). Unique alleles are those detected in a group of accessions but absent in other groups. Group specific unique alleles observed among the races were 40 in Indica, 21 in Moharia, 10 in Pumila, and 8 in Maxima, while region-wise unique alleles were 57 in South Asia, 17 in West Asia, 14 in East Asia, and 3 in Africa. The common alleles shared by two groups were 28 between Moharia and Indica, 16 between Maxima and Indica, 9 between

Maxima and Moharia, 4 between Moharia and Pumila, 3 each between Italica and Indica, and Pumila and Indica and one between Moharia and Italica. Region-wise shared alleles were 43 between East Asia and South Asia, 24 between South Asia and West Asia, 4 between Africa and South Asia, 3 each between East Asia and West Asia, and Africa and West Asia, 2 between Africa and East Asia and 1 between Europe and South Asia. A reference set consisting of 200 genetically most diverse accessions have been formed. This reference set captured 316 (87%) of the 362 composite collection alleles, representing diversity from the entire spectrum of composite collection. A journal article is under preparation.

Special Project Funding:
NA

HD Upadhyaya, A Bharthi, CLL Gowda, S Senthilvel, RK Varshney,
CT Hash, DA Hoisington, A Rathore and T Shah

Output target 2011 2.4.1 Datasets of composite collections of finger millet and foxtail millet genotyping made available globally via the internet

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Datasets for finger millet (1000 accessions with 20 SSR), and foxtail millet (500 accessions with 19 SSR) composite collection made available globally via the internet on http://www.generationcp.org/

Special Project Funding:
NA

HD Upadhyaya, S Senthilvel, CLL Gowda, A Bharthi,
RK Varshney, A Rathore and T Shah

Output target 2009 2.4.3 Trait specific germplasm of staple crops and small millets available for utilization

Trait specific germplasm regenerated/multiplied for distribution to partners on request (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Regenerated seeds of trait specific germplasm such as early maturing, large-seeded, high-yielding, high seed protein, and resistant/tolerant to salinity, high temperature, wilt, dry root rot, ascochyta blight, botrytis gray mold, and drought in chickpea; early maturing, large-seeded, high-yielding, high shelling percentage high seed protein, high seed oil, oleic acid, linoleic acid, oleic/linoleic acid ratio and resistant/tolerant to late leaf spot, early leaf spot, rust, bacterial wilt, *A flavus,* drought, low temperature at germination, and multiple resistance in groundnut; early maturing, large-seeded, high-yielding, high seed protein, high shelling percentage, vegetable type, and tolerant to salinity, wilt, sterility mosaic, and phytopthora blight in pigeonpea; early maturing, large-seeded, high-yielding, high seed zinc content, high seed iron content, and resistant to downy mildew in pearl millet; early maturing, large-seeded, high-yielding, high seed calcium high stalk sugar content, and resistant to grain mold, downy mildew, leaf blight, rust, and multiple resistant in sorghum; early maturing, high-yielding, high seed calcium, iron, zinc, protein content, and resistant/tolerant to drought, salinity, and blast diseases in finger and foxtail millet. Seed of these trait specific germplasm accessions was made available to partners on request under SMTA.
Special Project Funding:
NA

HD Upadhyaya, CLL Gowda, RP Thakur and NBPGR

Output target 2009 2.4.4 Germplasm reference sets available for utilization

Germplasm accessions of chickpea and groundnut reference sets regenerated for distribution to partners on request (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Regenerated the seed of 300 accessions of chickpea and 300 accessions of groundnut reference sets and distributed to partners on request under SMTA.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, CLL Gowda, RP Thakur and NBPGR</div>

Germplasm accessions of pigeonpea and sorghum reference sets regenerated for distribution to partners on request (2010)

Achievement of Output Target:
75%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Regenerated the seed of 300 accessions of pigeonpea and 375 accessions of sorghum reference sets and distributed to partners on request under SMTA.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, CLL Gowda, RP Thakur and NBPGR</div>

Output target 2.4.5 DNA extracts of mini core collections and reference sets of germplasm conserved for utilization (2011)

Output target 2010 2.4.1 DNA extracts of chickpea and groundnut mini core collections of germplasm conserved for utilization

Achievement of Output Target:
75%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Conserved DNA of 211 accessions of chickpea and 184 accessions of groundnut mini core collections.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, RK Varshney and CLL Gowda</div>

DNA of pigeonpea, groundnut, and sorghum mini core collections and reference set extracted and made available on request (2011)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
DNA of pigeonpea, groundnut, and sorghum reference sets made available and sent to CIRAD on request.

Special Project Funding:
NA

<div align="right">HD Upadhyaya, RK Varshney, CT Hash, CLL Gowda,
KB Saxena and RP Thakur</div>

DNA of finger millet mini core collections and reference set extracted and made available on request (2012)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
DNA of finger millet reference set made available and supplied to CIRAD on request.

Special Project Funding:
NA

HD Upadhyaya, A Bharathi, RK Varshney, CT Hash,
CLL Gowda and RP Thakur

Output target 2011 2.4.6 Broadening the genetic base of legumes through wide crosses

Diploid hybrids between Arachis AA and BB genome generated and reference map of AA and BB genome constructed (2010)

Achievement of Output Target:
No activity this year

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Not reported for 2009

Special Project Funding:
NA

N Mallikarjuna, RK Varshney and HD Upadhyaya

Hybrids between cultivated groundnut and synthetic amphidiploids created, variation for different traits (Rosette and foliar diseases) analyzed and molecular map constructed (2011)

Achievement of Output Target:
No activity this year

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Not reported for 2009

Special Project Funding:
NA

N Mallikarjuna, RK Varshney and HD Upadhyaya

Develop hybrids between section *Arachis* and section *Procumbentes* and generate fertile backcross population and screen for desirable traits (2010)

Achievement of Output Target:
50%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Advanced generation interspecific derivatives are available for the crosses *A. hypogaea* x *A. chiquitana* (BC$_3$F$_3$) and *A. hypogaea* x *A. kretschmeri* (BC$_3$F$_5$). BC$_2$ F$_1$ seeds from the cross *A. hypogaea* x *A. chiquitana* were screened for *Aspergillus flavus* infection (2002 – 03) and some of the seeds are found to be devoid of infection. The screening experiment could not be continued due to shortage of seeds. The effort this year was on the generation of more number of seeds to resume the screening experiment. Rust resistance and moderate levels of resistance to LLS was observed in *Arachis hypogaea* x *A. kretschmeri* derivatives.

Special Project Funding:
NA

N Mallikarjuna, RK Varshney and HD Upadhyaya

Tetraploid hybrids between synthetic and cultivated groundnut generated and molecular map generated for use in breeding program (2011)

Achievement of Output Target:
50%

Participating Countries:
India

Participating Partners:
UAS, Dharwad, India

Progress/Results:
Cultivated *A. hypogaea* was crossed with five new sources of *A. hypogaea* (synthetic groundnuts) and F$_1$ hybrids obtained were studied for recombination between cultivated and synthetic groundnuts. Some of the combinations used to generate new source of *A. hypogaea* were novel ones as such combinations were not available either through synthesis or naturally. For example ISATGR 265-5 is a combination of *Arachis* species *A. kempff-mercadoi* (A genome) *and A. hoehnei* (B genome). ISATGR 268-5 is a combination of species *A. batizocoi* (B genome) and *A. cardenasii* (A genome). ISATGR 72B is a combination of *A. duranensis* (A genome) and *A. cardenasii* (A genome). Whereas putative genome donors of cultivated *A. hypogaea* are *A. duranensis* and *A. ipaensis*. Crosses with ISATGR 1212 gave the highest percentage of pollen fertility (> 90 %) as ISATGR 1212 has the same genome donor species combination of *A. duranenesis* and *A. ipaensis* as the original combination which gave rise to cultivated groundnut. High pollen fertility is an indication that there is good recombination between parental genomes i.e. cultivated *A. hypogaea* and ISATGR 1212 (Table 17, Figure 4). In the remaining hybrid combinations, pollen fertility ranged from 62 to 82 %, again showing good recombination between cultivated and new sources of *A. hypogaea*.

Table 17. Pollen fertility analysis in the hybrids between cultivated *A. hypogaea* and new sources of *A. hypogaea*.

S. no.	F1 hybrid combination	Pollen fertility
1	*A. hypogaea* x ISATGR-1212	97.4
2	*A. hypogaea* x ISATGR-1212	93.7
3	*A. hypogaea* x ISATGR-1212	92.1
4	*A. hypogaea* x ISATGR-1212	92
5	*A. hypogaea* x ISATGR-1212	95.1
6	*A. hypogaea* x ISATGR-1212	92.4
7	*A. hypogaea* x ISATGR-265-5	62.8
8	*A. hypogaea* x ISATGR-265-5	65.81
9	*A. hypogaea* x ISATGR-265-5	66.16
10	*A. hypogaea* x ISATGR-278-18	73.4
11	*A. hypogaea* x ISATGR-278-18	73.2
12	*A. hypogaea* x ISATGR-278-18	73.71
13	*A. hypogaea* x ISATGR-278-18	69.4
14	*A. hypogaea* x ISATGR-278-18	74.3
15	*A. hypogaea* x ISATGR-72B	75.3
16	*A. hypogaea* x ISATGR-72B	66
17	*A. hypogaea* x ISATGR-265-5A	82.1
18	*A. hypogaea* x ISATGR-265-5A	69.9
19	*A. hypogaea* x ISATGR-265-5A	71.6
20	*A. hypogaea* x ISATGR-268-5A	61.9
21	*A. hypogaea* x ISATGR-268-5A	61.9
22	*A. hypogaea* x ISATGR-268-5A	73.4
23	*A. hypogaea* x ISATGR-268-5A	73.4

Some of the F$_1$ hybrids were backcrossed to their respective cultivated recurrent female parent to develop ABQTL population. Seed set was observed in the backcrosses (Fig. 1). Attempts are on to generate more number of BC$_1$ seeds.
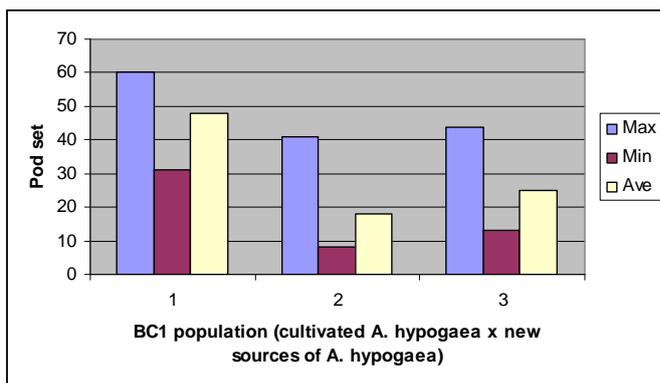
Foot note: 1: *(A. hypogaea* x ISATGR 1212); 2: *A. hypogaea* x ISATGR 265-5); 3: (*A. hypogaea* x ISATGR 268-5).
Figure 4. BC₁ seed set observed between F₁ hybrids (cultivated *A. hypogaea* and new sources of *A. hypogaea*)

N Mallikarjuna, HD Upadhyaya, RK Varshney, S Senthilvel and MVC Gowda

Generate variation for desirable characters using *Cajanus platycarpus* (2010)

Achievement of Output Target:
75%

Participating Countries:
India

Participating Partners:
PAU, Ludhiana India, UAS, Bangalore India

Progress/Results:
Selections made in 2007 and 2008 for a range of traits such as early flowering, high pod set, multiple seed color, short stature, low *H. armigera* damage, low phytophthora blight damage, high seed weight and stay green trait, were evaluated again in 2009. All the lines continued to show low *H. armigera* damage. Variation was observed for phytophthora blight disease, however one line continued to show low disease incidence. White seeded lines retained their color and some of the brown seeded lines showed variation for seed color. Male sterility observed in one of the lines was confirmed as CMS. The cause of male sterility was sterile pollen grains and non-dehiscence of anthers, and was maintained by cultivar ICPL 85010. Few lines were screened for Bangalore isolate of SMD and two lines were found to be promising. The screening experiment will be repeated in 2010 to confirm the resistance.

N Mallikarjuna, HC Sharma, HD Upadhyaya, RK Varshney,
KB Saxena, L Kaur and B Gowda

Output target 2011 2.4.7 Allele specific sequence diversity in the reference sets staple crops studied
Allele specific sequence diversity in the reference set of chickpea studied (2011)

Achievement of Output Target:
90%

Participating Countries:
France and Peru

Participating Partners:
Cirad, INRA-CNG, CIP

Progress/Results:
Chickpea: Under the Generation Challenge Programme sponsored 'Allelic Diversity on Orthologous Candidate genes' (ADOC) project, several drought responsive candidate genes such as CAP2 (homolog for DREB2A), CAP2 promoter, sucrose synthase (SuSy) (two fragments), sucrose phosphate synthase (SPS) (two fragments), abscisic acid stress and ripening gene (ASR) (two fragments) and ERECTA sequence have been identified. These genes were amplified and sequenced in a set of 8 chickpea genotypes and their allelic diversity was studied (Table 18 and Figure 5). These candidate genes, in collaboration with INRA-CNG (France) have been sequenced on a set of 300 accessions of the chickpea reference set. However, sequencing has been successful only for the CAP2, CAP2 promoter, SPS, ASR and ERECTA genes. Sequence diversity is analyzed using haplotyper tool developed at ICRISAT. The nucleotide diversity was highest in ERECTA (0.0029) and lowest in case of CAP2 (0.00). The haplotype diversity was found highest in case of ASR gene (0.829) and lowest in case of CAP2 gene (0.00). Further details of the sequence diversity are presented in the Table 19.

Table 18. Allelic diversity of drought responsive candidate genes in 8 diverse chickpea genotypes.

	ASR2	ASR5	CAP2gene	CAP2promoter	SPS2	SPS3	SuSy3	SuSy4
No. of Genotypes	7	8	7	8	7	8	8	8
Sequence length (bp)	848	668	707	603	494	371	739	755
No. of Indels	0	1	0	0	1	0	0	0
Indel Frequency	0	1/668.00	0	0	1/494.00	0	0	0
No. of SNPs	13*	3	0	2	16	0	5	6
Transition	9	2	0	0	8	0	4	1
Transversion	6	1	0	2	8	0	1	5
SNP frequency (bp)	1/65.23	1/222.67	0	1/301.50	1/30.88	0	1/147.80	1/125.83
Nucleotide Diversity	0.0063	0.0017	0.0000	0.0013	0.0132	0.0000	0.0026	0.0031
Avg. PIC of SNP	0.32	0.41	0	0.44	0.28	0	0.31	0.22
No. of Haplotypes	5	3	1	4	7	1	4	7
Haplotype Diversity	0.857	0.679	0.000	0.786	1.000	0.000	0.643	0.964
PIC of Haplotypes	0.735	0.594	0.000	0.688	0.857	0.000	0.563	0.844

*Triallelic SNPs

Table 19. Details of SNP diversity estimation in candidate drought responsive genes on reference collection of chickpea

Candidate gene	ASR	CAP2	CAP2 promoter	ERECTA_7f_5r	ERECTA_8f_8r	SPS
No. of Genotypes	193	227	137	79	147	235
Sequence length (bp)	621	367	529	921	1189	312
No. of Indels	2	0	0	1	0	1
Indel frequency	1/310.50	0	0	1/921.00	0	1/312.00
No. of SNPs	34*	0	1	13	20	3
Transition	22	0	0	9	10	2
Transversions	13	0	1	4	10	1
SNP frequency	1/18.26	0	1/529.00	1/70.85	1/59.45	1/104.00
Nucleotide Diversity(φ)	0.0014	0	0	0.0029	0.0029	0.0011
Avg PIC of SNP	0.1	0	0.43	0.27	0.1	0.01
No. of Haplotypes	4	1	2	4	3	4
Haplotype Diversity	0.833	0	0.438	0.372	0.324	0.034
PIC of Haplotypes	0.829	0	0.435	0.367	0.322	0.034

*one tri-allelic SNP at 391 position T/C/A

Werqiouyto[utpo

Allele specific sequence diversity in the reference set of sorghum studied (2011)

Achievement of Output Target:
No activity this year

Progress/Results:
Not reported for 2009

Output target 2011 2.4.8 Development of genomic resources for SAT crops

Novel set of microsatellite markers developed and characterized for chickpea, pigeonpea and groundnut (2010)

Achievement of Output Target:
90%

Participating Countries:
USA

Participating Partners:
JCVI, NCGR, UC-Davis

Special Project Funding:
Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Govt. of India)

Progress/Results:
1. Chickpea:
In addition to developing SSR markers from SSR-enriched libraries (Nayak et al. 2010, Theor Appl Genet) and BAC-end sequences, next generation sequencing (NGS) technologies (Varshney et al. 2009) are being used to develop novel set of markers. For instance, by using FLX-454 sequencing technologies, a total of 435,018 transcript reads were generated from normalized and pooled cDNA sample of more than 20 different tissues of genotype ICC 4958. These FLX-454 reads along with >21,000 Sanger ESTs (Varshney et al. 2009, BMC Genomics), those mentioned in Archival report-2008 were assembled together and a set of 103,215 Tentative Unique Sequences (TUSs) were derived for chickpea, with an average length of 459bp. A total of 26,252 SSRs were identified in 23,330 (22.6%) TUSs using MIcroSAtellite (*MISA*) tool. Among them mono-nucleotide repeats were highest with 24,428, followed by 893 tri-nucleotides, 743 di-nucleotides, 91 tetra-nucleotides, 51 penta-nucleotides and 46 hexa-nucleotides. The results of microsatellite search are shown in Figure 6 and Table 20. Primer pairs could be designed for 3,172 SSRs. After excluding mono-nucleotides, compound SSRs, and also the redundancy at threshold E-value of ≤1E-05, Query coverage of ≥30 and percent identity of >90%, a final set of 728 (Class-I) primer pairs were considered as novel in chickpea and will be further utilized for characterization in chickpea.

Table 20. SSR identification using *MISA* in chickpea 454/FLX sequence data.

|	
Total number of TUs examined	*1,03,215*
Total size of examined sequences (bp)	34,718,996
Total number of identified SSRs	26,252
Number of SSR containing sequences	23,330
Number of sequences containing more than 1 SSR	2,480
Number of SSRs present in compound formation	2,012
Mono-nucleotide repeats	24,428
Di-nucleotide repeats	743
Tri-nucleotide repeats	893
Tetra-nucleotide repeats	91
Penta-nucleotide repeats	51
Hexa-nucleotide repeats	46
Primer pair designed	3,172
Class-I primer pairs	728
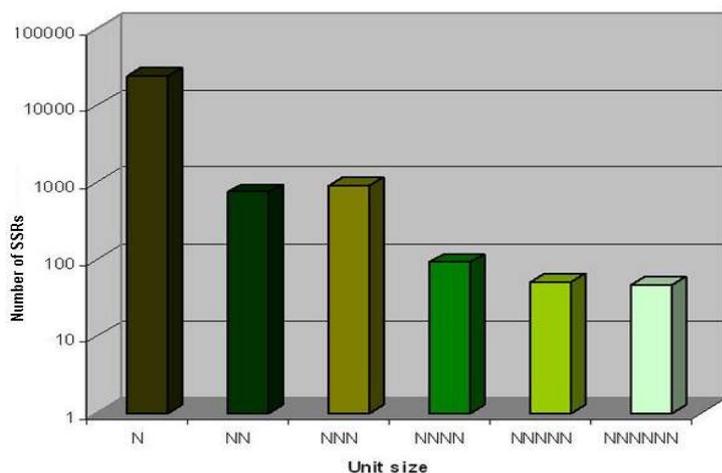
Figure 6. Distribution of different SSRs in chickpea transcriptome

<div align="right">RK Varshney, PJ Hiremath, CD Town, Y Xiao and AD Farmer</div>

2. Pigeonpea:
As mentioned in Archival Report- 2008, novel set of 23 SSR markers were developed from SSR enriched libraries. These results have been published in Plant Breeding (Saxena et al. 2009). In addition, two other approaches were used to develop microsatellite markers in pigeonpea.

1. Development of microsatellites from bacterial artificial chromosome (BAC) end sequences (BES): As mentioned in the Archival Report - 2008, 87,590 pigeonpea BAC-end sequences (BES) generated in collaboration with Doug Cook (USA), representing 56.5 Mb of genome, were surveyed for the presence of microsatellites using *MISA* search module. As a result, 18,149 pigeonpea microsatellites (1 SSR per 3.11 Kb) were identified. Oligonucleotide primer pairs were designed for 6,590 SSRs, out of these 3,072 primer pairs were synthesized and tested. Amplified products were obtained for 3,026 primer pairs and were used to identify polymorphism in a set of 24 pigeonpea genotypes that are parents of different mapping populations. Number of polymorphic markers identified ranged from 140-405 across different crosses.

2. Gene based markers: As a result of 454/FLX sequencing of cDNA pool of Pusa Ageti, a total of 494,353 sequence reads were generated. More than 50% sequence reads were longer than 200 bp. CAP3 analysis of these sequences reads provided 48,519 contigs. Assembly of 454/FLX ESTs and >10,000 Sanger ESTs (mentioned in Archival report-2008) resulted in 127,754 tentative unique sequences (TUS), these were screened to evaluate the presence of SSR motifs using *MISA* search tool. As a result 41,899 (32.7%) sequences were found to contain 50,566 SSRs with an average of one SSR per 570 bp (Table 21; Figure 7). Of these 41,899 sequences, 6,997 (16.6 %) sequences contained more than one SSR and 6,352 (15.1%) were compound SSRs. Primer pairs were designed for 12,377 SSRs including mononucleotide SSRs. A total of 8,023 primer pairs were considered for validation after excluding the primers that were designed for mononucleotide and compound SSRs.

<div align="right">RK Varshney, A Dubey, NL Raju, RK Saxena, Jayashree B,
DR Cook, CD Town, and AD Farmer</div>

Table21. Summary SSR search using *MISA* in pigeonpea 454/FLX and Sanger ESTs SSRs.

Total number of sequences examined	127,754
Total length of examined sequences (bp)	28,914,151
Number of reads containing SSRs	41,899 (32.7%)
Number of identified SSRs	50,566
Number of sequences containing more than 1 SSR	6,997
Number of SSRs present in compound formation	6,352
Frequency of SSR	1/0.5 kb
Number of mononucleotide repeats	33,262
No. of primer pairs designed	12,377
Primer pairs considered for validation	8,023
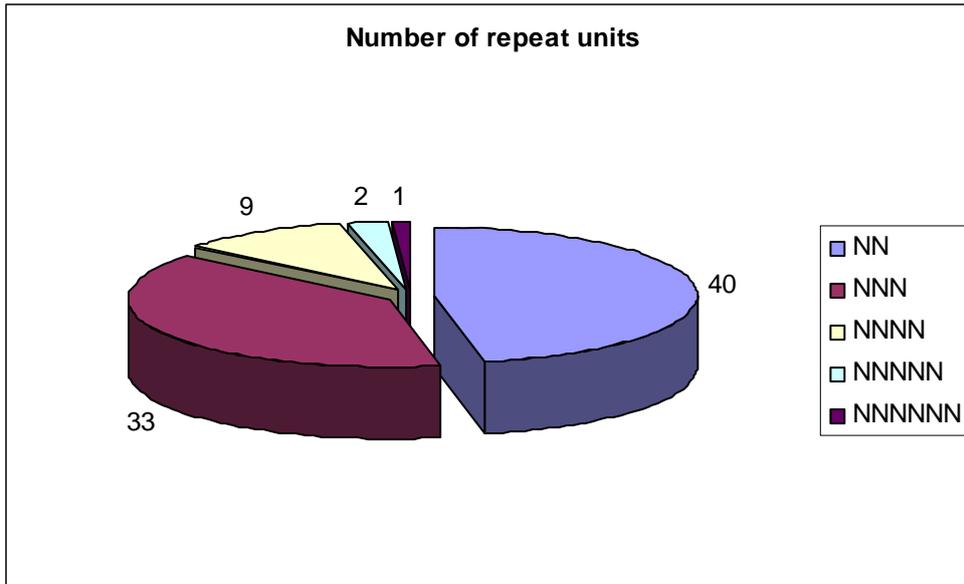
Figure 7. Distribution of microsatellites of different repeat units in ESTs of pigeonpea

3. Groundnut:
In continuation to the earlier report on development of SSRs from BAC end sequences in collaboration with University of California, Davis (Doug Cook), a total of 41,856 BAC end sequences (BES) spanning a length of 28.61 Mbp were mined for presence of SSRs. As result 4,869 SSRs were identified in 4,082 BES with a frequency of 1 SSR in 5.8 kb. Among different SSR repeat type classes mono- nucleotide SSRs were most abundant followed by di-nucleotide SSRs. Out of the 4,869 SSRs identified primer pairs were designed for a total of 1,152 SSRs. All these primer pairs are being used to screen parents of different mapping populations.

In another study a set of 23 novel genomic SSRs were isolated from microsatellite enriched genomic DNA library. The results based on this study have been published (Gautami et al. 2009; International journal of Integrative Biology 7: 100-106).

RK Varshney, B Gautami, K Ravi, DA Hoisington, and DR Cook

Output target 2011 2.4.2
Molecular genetic maps and consensus maps based on SSRs, DArTs and EST-based markers developed for chickpea, pigeonpea and groundnut (2011)

Achievement of Output Target:
80%

Participating Countries:
India, Germany, Australia and USA

Participating Partners:
University of Frankfurt (Germany) / University of California- Davis (USA), DArT, Pty Ltd, Australia

Progress/Results:
Chickpea
Different type of molecular markers e.g. SSRs and SNPs were used for genotyping the interspecific reference mapping population *Cicer arietinum* ICC 4958 × *C. reticulatum* PI 489777. The integrated map contains 521 loci organized into eight linkage groups that span 2,602 cM, with an average inter-marker distance of 4.99 cM. The results of this project have been published in Theoretical and Applied Genetics (Nayak et al. 2010; DOI 10.1007/s00122-010-1265-1). The integrated map has been given in Figure 8.

More markers such as Illumina –based SNPs, DArTs and other SSR markers are being integrated in this map to enhance the density of the genetic map.

Special Project Funding:
Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Govt. of India)

RK Varshney, S Nayak, T Mahendar, P Winter,
DR Cook and HD Upadhyaya
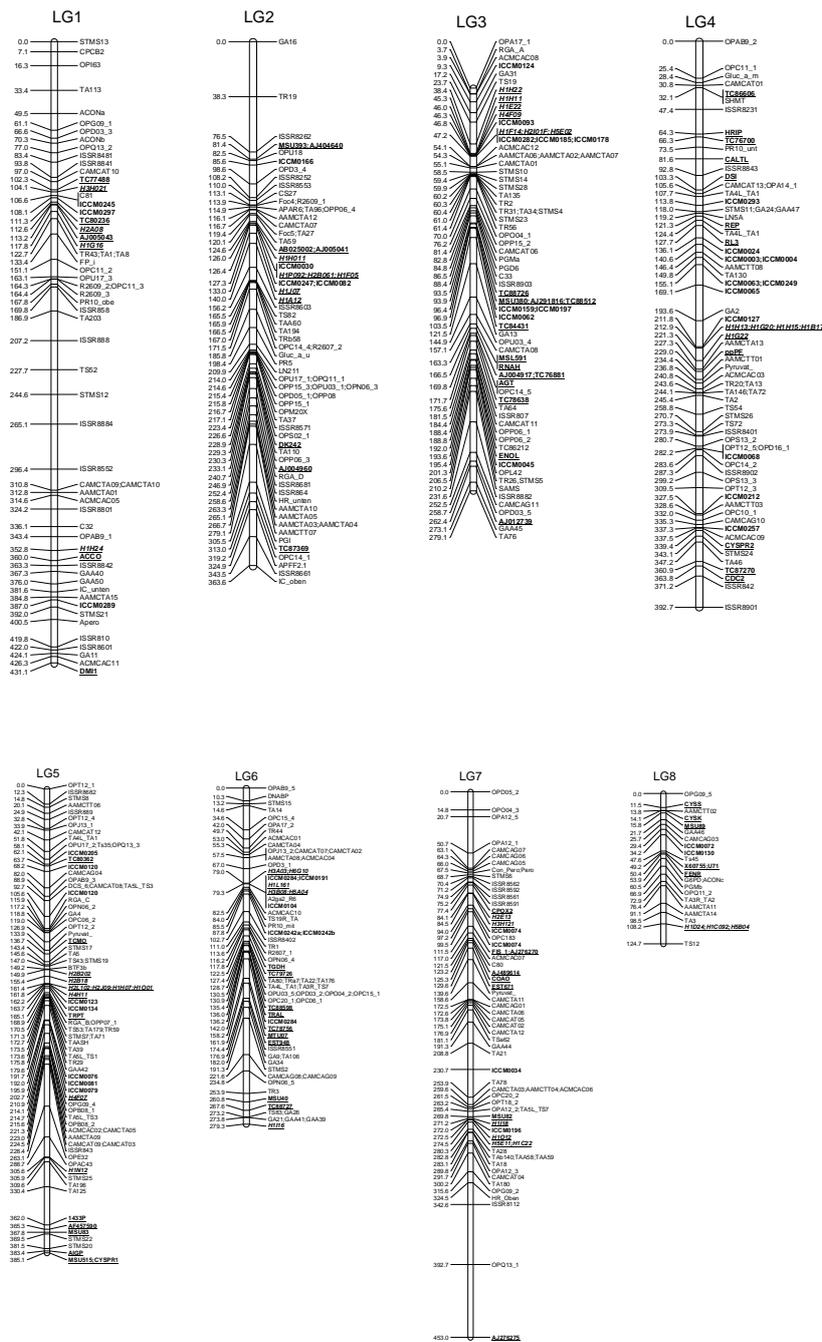
Figure 8. An integrated genetic map of chickpea based on recombinant inbred lines of *C. arietinum* **(ICC 4958)** × *C. reticulatum* **(PI 489777). Distances between the loci (in cM) are shown to the *left* of the linkage group and all the loci are at the *right side* of the *map*. Newly developed SSR markers developed from microsatellite enriched library (ICCM-series) are *bold* and *italicized*; SSR markers taken from Lichtenzveig et al. (2005) are *bold*, *italicized*, and *underlined*; SNP markers which were used as the anchor markers in comparative mapping of chickpea and *Medicago* were depicted as *bold* and *underlined*. Linkage groups (LGs) are designated according to the map of Winter et al. (2000).**

Groundnut:

Three RIL mapping populations of groundnut (ICGV 86031 × TAG 24, ICGS 44 × ICGS 76 and ICGS 76 × CSMG 84-1) have been used for developing the genetic maps for cultivated groundnut. A total of 3213 SSR markers available in public domain as well as unpublished markers available from different sources were screened on the parental genotypes of the three mapping populations. Number of polymorphic markers identified in different populations varied from 87- 211. The polymorphic markers identified were used for genotyping RILs of different mapping populations. Genotyping data based on polymorphic loci has been used to develop linkage maps for the three populations using MAPMAKER/EXP V. 3.0 programme. Features of these maps are given in Table 22. Genetic map for TAG 24 × ICGV 86031 has been published in Theoretical and Applied Genetics in 2009 (Varshney et al. 2009; Theor Appl Genet 118: 729-739).

<div align="right">RK Varshney, B Gautami, K Ravi, DA Hoisington,
SN Nigam and HD Upadhyaya</div>

Table 22. Salient features of groundnut linkage maps.

Mapping population	No. of polymorphic loci	No. of loci mapped	No. of loci/ LG (Avg)	Total map distance (cM)	Inter marker distance (cM) (Avg)
TAG 24 × ICGV86031	211	191	2-9 (8)	1786	2.90-24.34 (9.72)
ICGS 44 × ICGS 76	87	80	2-3 (5)	417	1.30-11.10 (5.48)
ICGS 76 × CSMG 84-1	128	98	2-1 (5)	1006	0.15-19.09 (8.56)

Pigeonpea:

An interspecific mapping population (*Cajanus cajan* ICP 28 × *C. scrabaeoides* ICPW 94) is being targeted for developing the reference map. SSR markers developed from BES were screened on a set of 24 pigeonpea genotypes that are parents of 12 mapping populations. As a result 145-405 polymorphic markers were identified on these parental combinations. About 300 polymorphic markers have been identified in the interspecific mapping population (*Cajanus cajan* ICP 28 × *C. scrabaeoides* ICPW 94). Genotyping of polymorphic markers in this population is underway.

In addition, in collaboration with DArT Pty Ltd, a total of 554 DArT markers were detected in the same mapping population. By using these markers, two groups of genetic maps were generated. A total of 121 unique DArT maternal markers were placed on the maternal linkage map (Figure 9). A total of 166 unique DArT paternal markers were placed on the paternal linkage map (Figure 10. The length of these two maps covered 437.3 cM and 648.8 cM, respectively.

RK Varshney, A Kilian, RK Saxena, A Dubey, KB Saxena and HD Upadhyaya
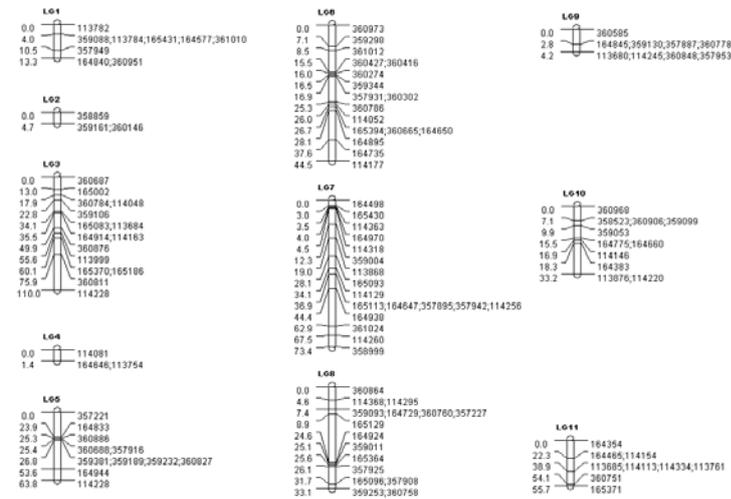
Figure 9. Pigeonpea linkage map using DArT maternal markers. Distances between the loci (in cM) are shown to the *left* of the linkage group and all the loci are at the *right side* of the *map*.
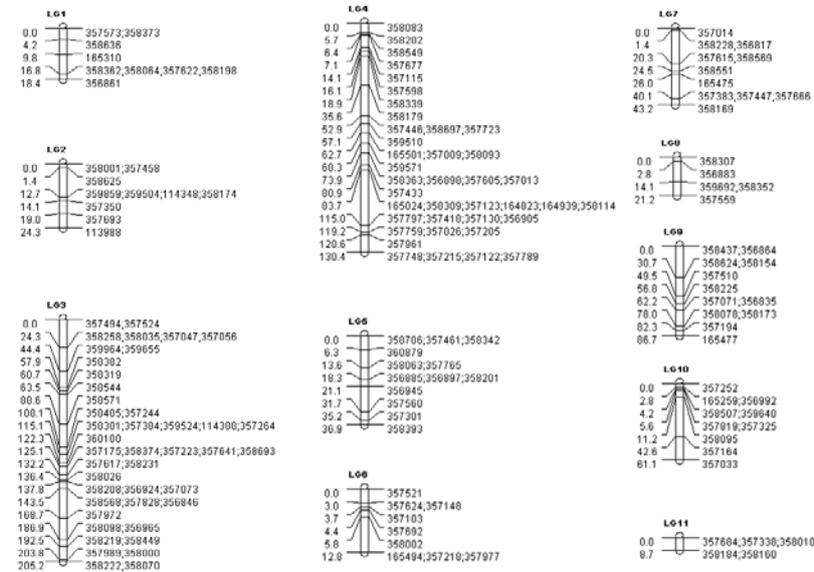

Figure 10. Pigeonpea linkage map using DArT paternal markers. Distances between the loci (in cM) are shown to the *left* of the linkage group and all the loci are at the *right side* of the *map*.

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Molecular genetic maps and consensus maps based on SSRs, DArTs and EST-based markers developed for pearl millet (2010)

Achievement of Output Target:
No activity this year

SSRs and EST-based marker positions identified on sorghum genome sequence, providing consensus map (2009)

Achievement of Output Target:
No activity this year

Output target 2010 2.4.9 Data management infrastructure development

Data submission, curation and fulfilling database interoperability requirements, generation of crop-specific trait ontologies (2009)

Achievement of Output Target:
80%
There has been a gap in recruitment of Bioinformatics scientist for a large part of the year.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Data sets have started to be uploaded into ICRIS data base. Crop ontologies have been developed in the OBO (open biomedical ontologies) format for chickpea and sorghum. The ontology browser is also available at http://koios.generationcp.org/ontology-lookup/

Special Project Funding:
NA

Jayashree Balaji, T Shah, HD Upadhyaya, . Gaur, and V Vadez

Data availability through GUI, web services and ongoing curation and generation of crop-specific trait ontologies (2010)

Achievement of Output Target:
50%

Participating Countries:
Mexico, India, Philippines, Colombia.

Participating Partners:
Bioversity, CIMMYT, ICRISAT, IITA, IRRI,.

Progress/Results:
Crop ontologies have been developed in the OBO (open biomedical ontologies) format for chickpea and sorghum. The ontology browser is also available at http://koios.generationcp.org/ontology-lookup

Special Project Funding:
GCP project

Jayashree Balaji, T Shah, HD Upadhyaya, P Gaur,
V Vadez, E Arnaud, R Shreshtha and R Mauleon

Ongoing data submission, curation, using ontologies for trait data processing (2011)

Achievement of Output Target:

Participating Countries:

Participating Partners:

Progress/Results:
This activity will be built on the ontologies reported above in 2010. Under the molecular breeding platform project, trait dictionaries will be developed from the crop ontologies available, eventually to be implemented in the Crop Information System.

Special Project Funding:

T Shah, HD Upadhyaya, P Gaur and V Vadez

All components of the Information system for MAB designed and developed (2009)

Achievement of Output Target:
80%
Due to a number of key staff changes the continuity and design of the software development was affected. Also due to limited experience with Eclipse RCP.

Participating Countries:

Participating Partners:

Progress/Results:
Information System for Marker-Assisted Breeding (ISMAB), has been developed. It can be used as a tracking and visualization system for MAB. The first component, the Molecular Breeding Design Tool (MBDT), has been developed that assists in the selection of suitable parents, provides visual integration of genotypic, phenotypic, map, pedigree and Quantitative Trait Loci (QTL) data and allows rich client-based interactivity and manipulation. It has been developed in Java using the Eclipse Rich client platform.

Special Project Funding:
DBT, India

Jayashree Balaji, T Shah, DA Hoisington,
CT Hash and T Napoleon

Information system for MAB tested, alpha version released and user training (2010)

Achievement of Output Target:

Participating Countries:

Participating Partners:

Progress/Results:
This will build on the ISMAB system developed. A workshop for training and receiving wider user requirements and feedback has been scheduled for May 2010.

Special Project Funding:

Jayashree Balaji, T Shah, DA Hoisington,
CT Hash and T Napoleon

Information system for MAB beta-version released and user training (2011)

Achievement of Output Target:
No activity this year

Participating Countries:

Participating Partners:

Progress/Results:
The ISMAB system is continuously being improved and is also a part of the decision support tools for the Molecular Breeding platform project. Continuous enhancements will be carried out in 2010 and 2011 to cover the two above mentioned activities.

Special Project Funding:

Jayashree Balaji, T Shah, DA Hoisington,
CT Hash and T Napoleon

Output target 2011 2.4.10 Development of data analysis tools

iMAS version2.0 released (2009).

Achievement of Output Target:
90%
One activity regarding integration of iMAS with GCP platform could not be completed. Possibilities of integration were also discussed with GCP platform developers and they were also of opinion that this integration may not be possible.

Participating Countries:
India, Philippines, Mexico, Australia, USA

Participating Partners:
IRRI, CIMMYT, CSIRO, NCGR

Progress/Results:
During 2009, QTL analysis module for was extended to incorporate multi-environment QTL analyses. For this ReML mixed linear model facilities in IRRISTAT was used to facilitate multi-environment phenotyping data analysis. The previous windows interface to PlabQTL in iMAS was appropriately extended to allow the user to correctly and easily undertake multi-environment QTL analyses. In Linkage Map Building module construction of consensus linkage maps was also implemented.

Software engineering requirements for integration of CMTV into iMAS was identified and appropriate input format for CMTV was generated. iMAS was also linked with Qu-Gene by generating Qu-Gene input files from within iMAS. In addition to that simple-to-use online guidelines with clear advice and caution has been updated into the system and explained in detail, with real examples, in the user manual.

To make iMAS more stable and bug free a beta testing workshop of iMAS was organised. For this users from Africa and Asia were identified and beta testing workshop was conducted during 24-26th August 2009 at ICRISAT, Patancheru. Participants tested iMAS with various diverse data sets and also gave various useful suggestions for improvement and stability of iMAS.

Based on feedback and suggestions from users, iMAS was improved further and finally training programme for African NARS was organized during 18–19th December, 2009 at the ESA Regional program office of ICRISAT at ILRI, Nairobi, Kenya. The workshop was attended by 21 participants from seven countries including Eritrea, Ethiopia, Ghana, Kenya, Sudan, Tanzania and Uganda. Training was largely appreciated by the participants. Based on feedbacks from training and testing workshops, iMAS 2.0 has been released and is available for download from the GCP and ICRISAT web sites.

Special Project Funding:
Generation Challenge Programme

<div align="right">A Rathore, CT Hash and T Shah</div>

Pipeline of open source tools for sequence, NGS data analysis, marker development and annotation (2009)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
NA

Progress/Results:
A pipeline of open source software extended to run on multiple CPU architectures that can be used to mine large EST datasets for SNPs and identify restriction sites for assaying the SNPs so that cost-effective CAPS assays can be developed for SNP genotyping in genetics and breeding applications. The pipeline has been implemented to run on a Paracel high performance system consisting of four dual AMD Opteron processors running Linux with MPICH. The pipeline can be accessed through user-friendly web interfaces at http://hpc.icrisat.cgiar.org/PBSWeb and is available on request for academic use. The developed pipeline was validated by mining chickpea ESTs for interspecies SNPs, development of CAPS assays for SNP genotyping, and confirmation of restriction digestion pattern at the sequence level. Many of these scripts are available in public domain (http://www.icrisat.org/newsite/bt-bioinformatics-sequence.htm).

Special Project Funding:
NA

<div align="right">Jayahshree B, RK Varshney, V Thakur, AB Prakash and R Pradeep</div>

Open source data analysis tools for comparative genomics made available, wrapped as web services (2010)

Achievement of Output Target:
90%

Participating Countries:
India

Participating Partners:
NA

Progress/Results:
A new set of modules and scripts for diversity statistic calculation, format parsing and data manipulation are available with PISE wrappers that enable pipelining of these scripts with commonly used contig assembly and sequence feature prediction software, to answer specific sequence diversity related questions. To enable the use of this software with other public domain tools, we also make available PISE (Pasteur Institute Software Environment) wrappers for these Perl scripts and module. This enables the user to generate pipelines for automated analysis, since PISE is a web interface generator for bioinformatics programmes. The results of this project are published in BMC Research Notes (Jayashree et al. 2009).

Special Project Funding:
NA

<div align="right">B Jayahshree, RK Varshney, T Shah,
V Thakur, AB Prakash and SN Nayak</div>

Sequence data analysis tools enhanced, users trained on use of tools through bioinformatics workflows (2011)

Achievement of Output Target:
60%

Participating Countries:
India, USA, UK

Participating Partners:
NCGR, TSL

Progress/Results:
In addition to developing tools for sequence analysis, ICRISAT has started to develop bioinformatic tools for analyzing the next generation sequencing (NGS) data, as these technologies are generating large amount of sequence data. ICRISAT is using NGS technology to generate EST and SNP marker resources to facilitate molecular breeding in mandated crops. NGS methods however generate a huge amount of data, the shorter read lengths require considerable bioinformatics effort in assembly. In collaboration with The Sainsbury Lab (TSL) and National

Centre for Genomic Resources (NCGR), ICRISAT has been engaged in putting public domain tool together to develop the pipeline. In this direction, ICRISAT has tested two commonly used NGS analysis tools (Maq, Novoalign) and also developed an adhoc approach. These tools and pipeline is being refined.

Special Project Funding:
NA

<div align="right">RK Varshney, V Thakur, B Jayashree, T Shah, AB Prakash,
R Pradeep, D Studtholm and GD May</div>

Users trained to carry out data analysis through bioinformatics workflows (2012)

Achievement of Output Target:
25%

Participating Countries:
Kenya, India

Participating Partners:

Progress/Results:
A number of training courses on bioinformatics tools were conducted. Examples of these include a training on LIMS for laboratory staff and also staff from ICRISAT-Kenya. Bioinformatics training was also conducted as a part of the CEG training courses.

Special Project Funding:

<div align="right">Jayashree Balaji, T Shah and RK Varshney</div>

Output target 2010 2.4.11 RILs and mapping populations of staple crops assembled for utilization

TILLING population of pearl millet developed (2009)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
NA

Progress/Results:
Generation of TILLING population, a comprehensive genomic resource for identifying novel allelic variants for the gene of interest and for functional validation, comprising genome-wide mutagenesis events is accomplished. The pearl millet TILLING population comprising 9938 M2 lines is generated from the inbred line "P1449-2-P1". All experimental details, data storage and management are being carried out using LIMS (Laboratory Information Management System; http://10.3.1.159:8080/lims). The summary statistics of TILLING lines is graphically represented in Figure 11. As mentioned in the earlier report, DNA isolations were carried out in phase wise manner (for instance DNA from 2694 M2 lines was isolated during 2006-07, DNA from 2074 lines in Summer 2007, 2791 lines in *Kharif* 2008 and 2379 lines in Summer 2008). All 9938 M2 line DNA were normalized to 5ng/μl. In order to identify allelic variants in candidate genes in cost effective and high throughput manner, eight fold pooling of all the normalized DNA samples was taken up. As a result 9938 M2 DNA samples could be accommodated into 12 pools. These populations are available for TILLING the candidate genes.
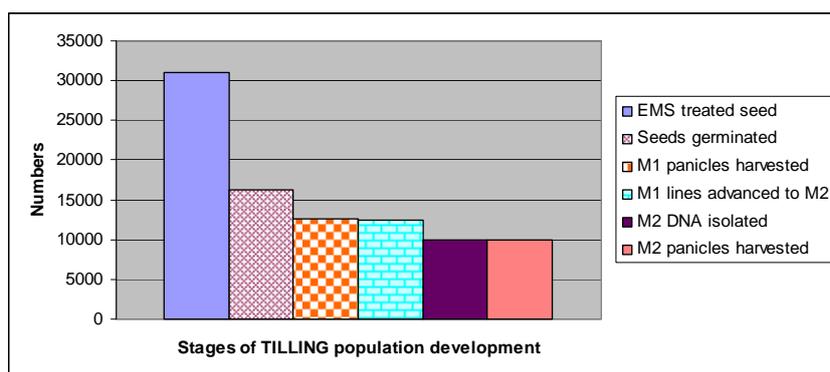

Figure 11. Graphical representation of number of seed/ TILLING lines at various stages of population development

Special Project Funding:
Department of Biotechnology (Govt. of India)

<div align="right">RK Varshney, T Mahendar, YP Khedikar, N Jalaja,
CT Hash and DA Hoisington</div>

Seed multiplied for RIL populations for different crops (2009)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Seeds of two groundnut RIL populations each (ICGV 99001 x TMV 2 and ICGV 99004 x TMV2) for late leaf spot resistance and (ICGV 99003 x TMV 2 and ICGV 99005 x TMV2) for rust resistance were multiplied. All the four RIL population were developed involving the trait specific interspecific derivates. Another rust and late leaf spot resistance RIL population of TAG 24 x GPBD 4 obtained from UAS, Dharwad was advanced to F_{12} generation. Similarly RIL population for rust and late leaf spot resistance involving TxAG 6(amphidiploid) and TMV 2 was developed and advanced to F_6 generation.

Developed 3 RIL populations (ICC 17160 x ICC 4958, ICC 17160 x ICC 8261, ICC 4958 x ICC 8261) for drought tolerance in chickpea, involving C. reticulatum and drought tolerant parent ICC 4958 and ICC 8261. These populations were advanced to F6 generations. Similarly 3 F_4 RIL populations and 6 F_3 RIL populations were developed for drought tolerance in chickpea. Seeds of these RILs are available in ICRISAT genebank.

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda and PM Gaur

DNA of different RIL populations isolated (2010)

Achievement of Output Target:
80%

Participating Countries:
India

Participating Partners:
IIPR, DGR

Progress/Results:
Large quantities of DNA (500 µg) from different mapping population of chickpea, pigeonpea and groundnut segregating for different traits was isolated (Table 23) and stored at -20ºC. These DNA are currently being used for genotyping with different markers. Further, this DNA will be made available to partners and research organizations on request.

Table 23. List of mapping populations available at ICRISAT .

Crop	Trait[*]	Mapping population	No of progenies
Chickpea	*Helicoverpa* resistance	ICC 4958 × PI 489777	131
	Root traits	ICC 4958 × ICC 1882	232
	Root traits	ICC 283 × ICC 8261	281
	Salt tolerance	JG 11 × ICCV 2	126
Pigeonpea	Fusarium wilt	ICPB 2049 × ICPL 99050	370
	SMD & Fusarium wilt	ICPL 20096 × ICPL 332	384
	SMD & Fusarium wilt	ICPL 87119 × ICPL 87091	124
	SMD	ICPL 20097 × ICP 8863	384
	Fertility restoration	ICPA 2043 × ICPR 2671	243
	Fertility restoration	ICPA 2043 × ICPR 3467	261
	Fertility restoration	ICPA 2039 × ICPR 2447	123
	Fertility restoration	ICPA 2039 × ICPR 2438	240
Groundnut	WUE and surrogate traits	TAG 24 × ICGV 86031	318
	WUE and surrogate traits	ICGS 44 × ICGS 76	376
	WUE and surrogate traits	ICGS 76 × CSMG 84-1	177

[*]SMD= sterility mosaic disease; WUE= water use efficiency

Special Project Funding:
National Fund of ICAR and Tropical Legume

Marker and phenotype databases for the available RIL mapping populations curated (2010)

Achievement of Output Target:
50%

Participating Countries:
USA

Progress/Results:
Molecular marker data are being generated and compiled for a number of mapping populations. Details about these marker data are given in the Table below (Table 24). Bioinformatics group is developing databases for storing the marker data.

Table 24. Compilation of marker data for different mapping populations.

Crop	Mapping population	Marker data generated
Chickpea	ICC 4958 × PI 489777	1533 (SSRs, DArTs, SNPs, etc.)
	ICC 4958 × ICC 1882	283 (SSRs, DArTs and SNPs)
	ICC 283 × ICC 8261	232 (SSRs and DArTs)
	JG 11 × ICCV 2	121 (SSRs and others)
Pigeonpea	ICP 28 × ICP 94	254 SSRs, 287 DArTs
	ICP 8863 x ICPL 20097	111 SSRs
Groundnut	TAG 24 × ICGV 86031	191 SSRs
	ICGS 44 × ICGS 76	88 SSRs
	ICGS 76 × CSMG 84-1	107 SSRs

RK Varshney, SN Nayak, M Thudi, K Ravi, K Jahnavi, A Bohra,
A Dubey, R Saxena, B Gautami, PM Gaur, HD Upadhyaya,
KB Saxena, SN Nigam, DA Hoisington and DR Cook

Output target 2010 2.4.4

Out put target 2010 2.4.12 Agriculturally beneficial micro-organisms assembled for utilization with associated capacity development

Agriculturally beneficial microorganisms from diverse environments accessed and characterized for 6 different traits – P-solubilization, antagonism to disease-causing fungi, pathogenicity to insect-pest, siderophore production (Annual)

Achievement of Output Target:
50%
This work is done using the funds of NBAIM funded AMAAS project and the AMAAS project ends only in year 2011. The rest 50% of the work is being planned in this year, 2010.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Evaluation and conservation of bacterial and actinomycete isolates, accessed from various herbal composts and sorghum and rice rhizosphere, for plant growth promoting traits including managers of insect pests, antagonists of fungal pathogens, P-solublization and siderophore production: A total of 137 actinomycete isolates were isolated from 27 different herbal vermicomposts and further screened for their ability to suppress growth of soil borne plant pathogens viz. *Macrophomina phaseolina* (MP), *Fusarium oxysporum* f sp *ciceri* (FOC), *F. udum* and *Sclerotium rolfsi*. None of the isolates inhibited *F. udum* and *S. rolfsi* whereas 79 and 33 isolates were found to be antagonistic to MP and FOC, respectively. A total of 10 isolates showed % inhibition between 60-87% for both FOC and MP. When 10 most effective isolates of MP were evaluated in green house on sorghum for their disease resistance, charcoal rot disease was not observed in control, however, PGP attributes were observed in the treatments where actinomycetes were inoculated. When the same isolates were evaluated for their PGP traits in green house similar trend was observed. All the 10 isolates increased shoot dry weight over control (between 6 and 31%), maximum being in CAI 21 (31%) followed by KAI 26 (30%), CAI 24 (29%), MMA 32 and KAI 180 (27%). Significant increase in root dry weight was also observed in MMA 32 (45%) followed by CAI 21 (29%), CAI 26 (19%) and CAI (17%).

In an another study, bacterial isolates (isolated last year from SRI field) were characterized for P-solublization, siderophore, fluorescent and IAA production and the most promising 7 isolates (SRI 151, 156, 158, 211, 229, 305 and 360) were further evaluated in green house on sorghum for their PGP ability. All the isolates and their consortia had increased shoot dry weight over control whereas maximum increase was observed in SRI 211 (95%) followed by SRI 178 and 156 (80 and 61%, respectively).

A total of 12 potential isolates, 7 bacteria (SRI 156 [*Pseudomonas ayucida*], SRI 158 [*Brevibacterium linens*], SRI 178 [*Bacillus pumilus*], SRI 211 [*Enterobacter agglomerans*], SRI 229 [*E. agglomerans*], SRI 305 [*Acinetobacter johnsonii*] and SRI 360 [*P. ayucida*]) and 5 actinomycetes (CAI 17 [*Streptomyces parvus*], CAI 21 [*S. albus*], CAI 26 [*S. champavatii*], CAI 78 [*S. globisporus*] and MMA 32 [*S. roseoviolaeus*]) were identified by 16s rDNA gene sequence analysis and submitted to NBAIM.

S Gopalakrishnan

Existing collection of agriculturally beneficial microorganisms conserved for medium and long-term storage system and annually 20% germplasm attended (Annual)

Achievement of Output Target:
50%
The newly purchased freeze drier was installed only on 9th Oct 2009 and hence it was not possible to finish the 20% germplasm target. It will be taken care of in this year, 2010.

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Conservation of already isolated plant growth promoting bacterial and actinomycete isolates from medium and long term preservation: freeze dryer that was essential for storing our potential PGPR and biocontrol cultures in lyophilized form (long term preservation) was acquired. Though the instrument arrived on 22nd July, it was installed only on 9th Oct due to various problems in installation. We started working on long term preservation of our important cultures on 28th Oct and so for we have stored 15 rhizobia (5 pigeonpea rhizobia [IC 3195, 4059, 4060, 4061 and 4062], 6 chickpea rhizobia [IC 59, 76, 2002, 2018, 2059 and 2099] and 4 groundnut rhizobia [IC 7001, 7017, 7029 and 7113]), 12 PGP and biocontrol bacteria (EB 13 and 35, BCB 19 and 114, HIB 28, SRI 156, 158, 178, 211, 229, 305 and 360) and 14 PGP actinomycetes (CAI 17, 21, 24, 26, 68, 78, 121 and 127, KAI 26, 27, 32, 90 and 180).

Identification of potential plant growth promoting bacterial and actinomycete isolates by molecular means: A total of 12 potential isolates, 7 bacteria (SRI 156 [*Pseudomonas ayucida*], SRI 158 [*Brevibacterium linens*], SRI 178 [*Bacillus pumilus*], SRI 211 [*Enterobacter agglomerans*], SRI 229 [*E. agglomerans*], SRI 305 [*Acinetobacter johnsonii*] and SRI 360 [*P. ayucida*]) and 5 actinomycetes (CAI 17 [*Streptomyces parvus*], CAI 21 [*S. albus*], CAI 26 [*S. champavatii*], CAI 78 [*S. globisporus*] and MMA 32 [*S. roseoviolaeus*]) were identified by 16s rDNA gene sequence analysis and submitted to NBAIM.

Special Project Funding:
NA

<div align="right">S Gopalakrishnan</div>

Requested agriculturally beneficial microorganisms distributed to bonafide users for utilization (Annual)

Achievement of Output Target:
100%

Participating Countries:
NA

Participating Partners:
NA

Progress/Results:
Production and supply of *Rhizobium* and other PGPR to ICRISAT as well as NARS Scientists: Carrier based different rhizobial (chickpea, pigeonpea and groundnut) inoculants (27 units; one unit is sufficient to cover one acre of land) and 12 rhizobial strains of chickpea, pigeonpea and groundnut (in slopes) were supplied on request from NARS, BRC partners, farmers and peer scientists at ICRISAT (list attached separately). Further, three units of entomopathogens (2 units of *Metarhizium anisopliae* and one unit of *Bacillus subtilis* BCB 19) in slopes were supplied to BRC partners (List attached separately). In addition to that, 4kg of BCB 19 was mass multiplied and supplied to AG Biosystems (BRC member) for evaluating the possibility of preparing BCB 19 in water soluble plastic pockets so that delivery of it could be made easy to the consumers (farmers).

Special Project Funding:
NA

<div align="right">S Gopalakrishnan</div>

MTP Project 3: **Producing more and better food from the staple cereals and legumes of the west and central African (WCA) SAT (sorghum, pearl millet and groundnut) through genetic improvement**

Project Coordinator: **Eva Weltzien Rattunde**

Highlights for 2009

The crop improvement team in West and Central Africa has seen certain changes in personnel: Dr. Benoit Clerget, Ecophysiologist on secondment from CIRAD, has left the region. Similarly the nutritionist, Marjolein Smit has left the team during the year. The team of the West African Seed Alliance Seed Project has grown significantly with the recruitment of a seed production specialist, and national coordinators for each project countries, Nigeria, Mali, Ghana, Senegal and Niger. The WASA partner CNFA has in addition recruited the WASA administrator, as well as a marketing specialist.

Research on food safety and aflatoxin contamination, primarily of groundnuts, but also in other food consumed by young children has been increasing with the acquisition of several sources of funding for targeted research questions. Laboratory facilities for aflatoxin analysis have been established at the Samanko station, and can be used for groundnuts, as well other food contamination with aflatoxins.

Groundnut breeding efforts have lead to the identification of a series of high yielding lines, with a high level of resistance to aflatoxin contamination. These varieties will be tested in multi-location trials, to assess also their potential for adoption. A groundnut minicore collection, as well as the groundnut reference set of germplasm lines have all been tested under conditions that encourage aflatoxin contamination, to test for resistance.

The cereal breeding group in West and Central Africa has achieved the first steps towards operationalizing heterotic groupings for the development of hybrid parents. The identification of distinct groups of germplasm has been made on the basis of SSR marker differentiation, phenotypic characterization of lines per se, and evaluation of the patterns heterosis expressed in crosses between varieties representing different groups of material.

Sorghum hybrid development and testing continue with strong efforts and growing interest particularly in Mali and Nigeria. Farmer managed hybrid seed production has been expanded. Seed production of open-pollinated varieties of sorghum and pearl millet has increased significantly as well in response to rising demands from a wide range of clients, such as farmer organizations, the private sector, and development projects. Farmers and farmer organizations show strong interest to continue and increase production of both OPV and hybrid varieties.

Evaluation of pearl millet population progenies has shown that significant progress has been made for grain yield. The selection practiced by individual farmers provided gains that were expressed across a range of target sites. Further, the selections made by a women farmer showed advantages in both the lower productivity womens' conditions as well as averaged over all test conditions.

The cereal team organized a joint end of project workshop for the BMZ-funded Mobilizing Diversity project, and the IFAD funded PROMISO project, in Niger. The proceedings were published as series of highlights, in hardcopy form, as well as on the Fidafrique website.

The publication of the book "Plant Breeding and Farmer Participation" provides both the conceptual framework and "hands on" experience for successful priority setting, planning, and implementation of participatory breeding undertakings. This book, published by FAO, will bring the work and experience of ICRISAT and other breeders to a global audience.

The project 3 in WCA has trained a large number of degree students over the year 2009, mostly conducting research for their theses. They came from at least 8 different countries, worked on all the three crops, and covered a wide range of disciplines from systems agronomy, plant breeding to human nutrition and social sciences. The team has also hosted, or co-organized several large research meetings in Bamako: The GCP annual Research Meeting, the BMGF funded TL2 and TL1 Annual project meetings; The Global Groundnut research conference and the launching meeting of the BMGF funded HOPE project.

Output 1: Heterotic relationships identified within sorghum and pearl millet germplasm adapted to WCA conditions and appropriate broad-based breeding populations and hybrid parents and knowledge made available to NARS and other partners in order to maximize genetic gain from selection

Output target 2009 3.1.1 Initial heterotic groupings for sorghum and pearl millet hybrid breeding for WCA established and publication drafted

Pearl millet:

Achievement of Output Target:
75%.
Multi-location germplasm characterization and combining ability field studies are completed. Field data analysis is lacking behind schedule because it requires a lot of time to collect and "clean" data of the partners. Molecular characterization using SSR markers has been completed, but is currently being complemented by DArT markers to enhance the relationship among molecular and field data.

Participating Countries:
Senegal, Mali, Burkina Faso, Niger, Nigeria

Participating Partners:
ISRA, IER, INERA, INRAN, LCRI, ICRISAT-India, University of Hohenheim

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Progress/Results:
Based on the SSR marker data, a dissimilarity matrix was computed for 241 West African pearl millet accessions. To some extend, genetic distances do correspond to geographic distance, with accessions from Senegal being genetically distant from accessions from Niger and Nigeria, while accessions from Mali and Burkina Faso range in between. However, large genetic diversity and distinct clusters can also be observed within each country. In order to enhance potential linkages between marker and phenotypic diversity, the same accessions will be genotyped with DArT markers in early 2010.

In 2009, available combining ability data from population crosses were complemented by production and evaluation of testcrosses derived from crossing new WCA pearl millet inbred lines on two broad-based population testers belonging to different heterotic groups (One from Senegal, one from Niger). The gained data will serve validation of putative heterotic groups through comparison of putative intra- and inter-pool crosses. A MSc student (C. Böhm) is working on this aspect for his MSc thesis. Based on the gained data, it is expected to complete the initial heterotic grouping in 2010. However, it may also be noted that heterotic grouping is a dynamic process with continuous iterations and refinements that will have to take place in the future breeding research.

BIG Haussmann

Sorghum:

Achievement of Output Target:
100%
Major activities conducted included a) quantifying and characterizing heterosis obtained by hybridizing Guinea-race sorghums that represent the global diversity of this race, and b) assessing the combining ability of currently available sorghum hybrid parents adapted to the Sudanian zone of West Africa. Additionally, molecular marker analyses of a set of 229 West African accessions of potential interest as hybrid parents is underway. One PhD dissertation is published and a second is in preparation. The first manuscript for a journal article has been drafted.

Participating Countries:
Mali, Nigeria, Niger, Senegal, Ghana

Participating Partners:
IER, IAR-Samaru, INRAN, ISRA-Bambey, SARI

Progress/ results:
Heterosis Study:
The extent and pattern of heterosis in Guinea-race sorghum hybrids were studied to determine possibilities for successful hybrid breeding and heterotic pool identification in this race. A two year study was conducted in Mali and Niger with hybrids (n=77) produced by crossing Guinea-race male parents originating in the Sudanian- (13) and Guinean- (7) zones of West and Central Africa, Eastern and Southern Africa (6) and Asia (2) to three A-lines developed from Malian (2) and Sudanese (1) landrace varieties.

Better parent heterosis (H_{bp}) ranged from 9.8 to 44.6% for the eight environments averaged over all hybrids tested, and from 12.8 to 63.8% for hybrids on the best female parent, FambeA. Mean H_{bp} of FambeA hybrids over environments was 30.3%. Absolute yield superiorities over better parents ranged from 169 to 558 kg^{-ha} for all hybrids across the eight environments, and from 228 to 807 kg^{-ha} for FambeA hybrids. The hybrid yield superiorities indicate that Guinea-race hybrids can provide agronomically useful advantages over traditional landrace varieties. Although one or more male parents from each geographic region produced superior hybrids with high heterosis, male-parents from the more humid Guinea-zone of West and Central Africa and from Southern Africa showed greatest promise when crossed with female parents from the drier Sudanian zone of West and Central Africa.

The PhD dissertation written by Sokona Dagnoko is based on this study. The first manuscript "Patterns of Heterosis for Grain Yield of Guinea Race Hybrids" has been drafted.

Combining Ability Study:
The first series of sorghum hybrid parents specifically developed for the Sudanian zone of West Africa are based on landrace- and improved breeding materials of Guinea-race origin as well as Guinea x Caudatum inter-racial breeding products. The combining abilities of five females parents (3 Inter-racial and 2 Guinea) and 12 males parent (6 Inter-racial and 6 Guinea) were assessed. A total of 60 hybrids were tested together with 6 check varieties over two years in four environments per year.

Male parents of Inter-racial and Guinea-bred origins had the most frequent positive general combining ability (GCA) values over environments whereas Landrace-Guinea and the more Caudatum-phenotype breeding lines often had negative GCA values. Female Parents showed important genotype x environment interaction. The ratio of male-GCA/SCA ranged from 1.5 to 5.0.

The mean performance of Inter-racial-, Guinea-, and Inter-racial x Guinea hybrid groups differed significantly for grain yield in all environments. The Inter-racial group produced the highest mean hybrid yields under high fertility conditions at Samanko and Sotuba. Under the Low-P conditions in contrast, the Inter-racial x Guinea group of hybrids had the highest mean yields, followed closely by the Guinea group. Each group of hybrids had some hybrids significantly superior to the mean of all hybrids, although the frequency differed substantially among groups over the test environment.

The SSR marker analyses characterizing the 229 accessions have been conducted. The multivariate distance analysis conducted on this material, indicated that interracial accessions do have intermediate distances from both the guinea race lines, and the caudatum race lines. No clear relationships between geographica distance and genetic distance estimates were found. We are preparing for an additional analysis with DART markers, to improve the differentiation between the different lines.

Output target 2010 3.1.1 Five new pearl millet and five sorghum inbred lines with good combining ability identified and characterized; seed made available to partners with associated capacity development for developing hybrid cultivars

Sorghum

Achievement of Output Target:
75%
National Sorghum Improvement Programs were provided seed of parental lines to establish hybrid crossing blocks. Production of experimental hybrids and collaborative regional testing were conducted.

Participating countries:
Mali, Nigeria, Ghana, Burkina Faso

Participating Partners:
IER, IAR-Samaru, IAR-Kano, SARI, INERA

Progress/ results
National Sorghum Improvement Programs were provided seed of parental lines to establish crossing blocks. A considerable number of experimental hybrids were produced by the collaborating national programs.

Number of experimental hybrids produced by West African NARS.

Institute	Location	Country	Number of Experimental Hybrids Created
IER	Cinzana	Mali	33
IER	Sotuba	Mali	105
SARI	Tamale	Ghana	60
IAR	Kano	Nigeria	23
IAR	Samaru	Nigeria	99
INERA	Saria	Burkina Faso	36

Extensive testing of experimental sorghum hybrids has been conducted with NARS partners in West Africa to assess yield and adaptation of the range of hybrids produced with currently available parental lines.

Number of experimental sorghum hybrids evaluated in replicated yield trials in West Africa by NARS partners and ICRISAT.

Zone	N. Sudanian		S. Sudanian					Guinean
# Hybrids tested	Bambey Senegal	Saria Burkina Faso	Bengou Niger	Samanko 1st Date Mali	Samanko 2nd Date Mali	Sotuba Mali	Sinthiou Senegal	Samaru Nigeria
2005	8	24	41	66	82	48	20	8
2006	12	12	16	18	55	55	16	18
2007	15	15	20	20	30	25	20	35
2008	0	28	0	34	34	28	28	28

Based on these experiments the following seed parents have been widely exchanged with by partners: GPN 271-20A/B, Fambe A/B, IPS001 A/B. A wide range of restorer lines has been found. The following restorer lines have shown good general combining ability and have been used widely: Lata 3 (Balla Berthe), IS6371, CSM 63 E.

Special Project Funding:
USAID through the West and Central African Sorghum Research Network (WACSRN/ROCARS) (ended 2008)

HFW Rattunde

Pearl millet:

Achievement of Output Target:
75%.
Field evaluation of line performance *per se* and test-cross performance successfully conducted at Sadore in rainy season 2009. Data analysis is underway. All available lines are being advanced/ multiplied in the off-season 2009-10 for future seed distribution to partners.

Participating Countries:
Niger

Participating Partners:
LCRI, INRAN, INERA, IER, ISRA for capacity building and sharing of seed; University of Hohenheim

Progress/Results:
Development of new inbred lines in WCA genetic background at ICRISAT-Niamey had started in 2005. In the reporting period, 210 new WCA inbred lines (>S5 generation) were advanced/multiplied in the off-season 2008/09; characterized for line performance *per se* and partially also for combining ability in the rainy season 2009; and are being multiplied in the running off-season of Nov 2009 for future seed distribution. Data analysis and summary of *per se* performance and combining ability effects is underway, as part of the MSc thesis of Mr Christof Böhm (University of Hohenheim).

Special Project Funding:
BMZ "Mobilizing regional diversity" for combining ability studies.

BIG Haussmann

Output target 2011 3.1.2 Five pearl millet inbred lines, and 2 populations with high general combining ability backcrossed into male-sterility inducing A4 cytoplasm

Pearl millet:

Achievement of Output Target:
50%.
Inbred lines and populations with high GCA identified for crossing; crossing block with A-lines planted in the off-season 2009-10.

Participating Countries:
Niger

Participating Partners:
None, but final A/B line pairs arising from this target will be shared with NARS in WCA..

Progress/Results:
General combining ability effects of 210 new pearl millet inbred lines in WCA genetic background are currently being estimated from test-cross evaluation under low and high-input conditions in rainy season 2009 at Sadore. The testers used in this study were two broad-based testers belonging to two different putative heterotic groups (one tester from Senegal, one from Niger). In addition, 30 lines have been crossed on the male-sterile line 17A to determine whether the lines maintain sterility or restore fertility in the hybrid. Data analysis is still underway, but initial results indicate a prevalence of maintainer types and lack of good restorers in the studied germplasm. More crosses of new WCA lines on male sterile lines (3 different cytoplasms) are being produced in the off-season 2009/2010 for evaluation in rainy season 2010. Maintainer types with good combing ability and *per-se* performance will be converted to A/B line pairs in the following off-season 2010/11 (production of BC1) and rainy season 2011 (production of BC2).

Special Project Funding:
No

BIG Haussmann

Sorghum:

Achievement of Output Target:
50%
The first sorghum hybrids are registered in Mali. Major hybrid development activities have been initiated in Nigeria.

Participating Countries:
Mali, Nigeria

Participating Partners:
IER, IAR-Samaru

Progress/results
Collaboration with the IER-Mali program involves jointly conducting experimental hybrid nurseries of approximately 200 hybrids per year, on-station hybrid yield testing of between 30 to 60 hybrids per year, and farmer-participatory testing of the most promising hybrids. This work has lead to the registration in Mali of the first four sorghum hybrids based on parents developed by IER and ICRISAT over the past decade.

Hybrid development activities in Nigeria have been substantially scaled up in 2009. Sorghum breeding materials for testing were assembled by ICRISAT and the Institute for Agricultural Research (IAR). These materials includes : a) Advanced experimental hybrid trials (n=4) with hybrids produced on currently available female parents with known restorer lines conducted in Kaduna and Kano States to assess performance targeting the Guinean and the Sudanian zones of adaptation , b) Initial experimental hybrids nurseries (n=2) to enable both identification of promising hybrids to promote to multi-environment testing, and identify male parent lines that show promise for further use with additional female parents, c) testcrosses from plant-to-plant crosses; for exploiting intra-line variability for fertility restoration, and absence of B1B2 testa genes, to develop breeding lines that can be used as hybrid parents, d) Segregating F2 populations of crosses between bold-grain and maintainer lines to initiate development of new female parent "A/B" parent lines that possess required grain characteristics and adaptation to the target production zones.

Special Project Funding:
USAID Task Order2 Hybrid Development for Nigeria
The Rockefeller Foundation (ended 2008)

HFW Rattunde

Output 2: Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management strategies to overcome key environmental and socio-economic constraints and making them available with new knowledge to partners

Output target 2009 3.2.1 First availability of allele-specific molecular markers for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum

Pearl millet and sorghum:

Achievement of Output Target:
75%.

Candidate genes have been identified for both sorghum and pearl millet; amplified; and single nucleotide polymorphisms (SNPs) determined. Population structure has been analysed and results for sorghum submitted for publication. The final association studies are underway and shall be completed in early 2010.

Participating Countries:
Niger, Mali, Germany

Participating Partners:
University of Hohenheim, CIRAD

Progress/Results:
Sorghum: A set of 219 West African cultivated sorghum accessions with differing maturities was assembled for association study of photoperiod sensitivity using a candidate gene approach. The accessions were chosen to represent a broad phenotypic diversity of photoperiodic response to flowering and were grouped into early ($n = 60$), intermediate ($n = 80$), and late flowering ($n = 90$) accessions based on previous analyses. The collection represents sorghum materials adapted to the drier Savanna (Burkina Faso, Mali, Niger, and Senegal) as well as the wetter savanna (Nigeria, Cameroon and Chad Phenotyping for photoperiod sensitivity was conducted with two sowing dates, 4 June and 4 of July in 2007. Each group was sown separately with two replicates per date. Leaf samples were taken from these plots for DNA extraction.

Final analysis of marker-trait association for six polymorphic candidate genes (Cry1, Cry2, Lhy, GI, Hd6 and D8) in sorghum is underway. Analysis is being done using a special R-code programmed by B.S. Stich (Max-Plank Institute, Köln, Germany). Important genes such as Heading date 1, Heading date 3a, Elf3, and Phytochrome A B C were also amplified but the polymorphisms found in the sequences were not sufficient for further analysis. Likewise, repeated amplification attempts for genes Heading date 1 and 3a with newly designed primer pairs did not show sufficient results.

Pearl millet:
Final marker-trait association analysis on pearl millet for five polymorphic candidate genes (PhyA, PhyB, PhyC, D8 and GI) is being done by SU Bhosale, Dr Heiko Parzies and Merima Alisic. Several newly designed primers for important candidate genes such as Heading date 1, Heading date 3a, and Heading date 6 were also tested but did not achieve suitable amplifications.

The results of the analyses for sorghum and pearl millet will be available in the course of 2010. The results will then be submitted for publication.

DArT analysis: Because it was not possible to establish more candidate genes in sorghum and pearl millet, we decided to include the use of mapped diversity array technology (DArT) markers in order to find associations with flowering time and photoperiodic response. DArT analysis will be done at ICRISAT in India in early 2010, and data analysis at UH thereafter.

Special Project Funding:
BMZ "Mobilizing regional diversity"

<div align="right">BIG Haussmann with University of Hohenheim and HFW Rattunde</div>

Output target 2009 3.2.2 One new genepool of pearl millet with reduced Striga susceptibility available for testing in West African breeding programs

Pearl millet

Achievement of Output Target:
100%.
Four cycles of recurrent full-sib (FS) and/or S1-family selection for below-average Striga emergence and above-average head weight completed with selections based on results of field evaluations at Cinzana (Mali, natural Striga infestation) and Sadore (Niger, artificial Striga infestation). While continuously being improved, the genepool can now also be shared with partners. First experimental cultivars extracted from the pool in 2009 revealed above-average performance and below-average Striga infestation in 2009 field trials.

Participating Countries:
Niger, Mali

Participating Partners:
IER; germplasm pool to be shared with LCRI, INRAN, INERA, IER and ISRA

Progress/Results:
In 2009, the full-sib (FS) evaluation of the fourth selection cycle was successfully achieved. 200 FS families were evaluated at Sadore and Cinzana, another 99 (those with less seed) only at Sadore. The year 2009 was an excellent Striga year and repeatability estimates for individual Striga resistance traits amounted up to 68.3% at Sadore and 77.4% at Cinzana, pointing to very good experimental quality at the individual sites. However, in the combined analysis across Sadore and Cinzana, the genotype x environment (GxE) interaction variance was highly significant and almost doubled the size of the genetic variance component, resulting into relatively low heritability estimates for Striga resistance measures (around 40% for log-transformed data), and pointing to the fact that different entries were superior at the two test sites. This could be due to the differing resistance reactions depending on soil and climate differences at the sites, but also due to potentially differing Striga virulence in Sadore *versus* Cinzana. Best FS families at each site (based on a selection index combining Striga emergence and head yield) will be recombined to form new experimental cultivars with specific adaptation to each site. Furthermore, new FS families will be created in the off-season of January 2010 to initiate the next selection cycle.

Special Project Funding:
McKnight Foundation Germplasm project; future funding through HOPE

<div align="right">BIG Haussmann</div>

Output target 2009 3.2.3 Knowledge of adaptation and initial regional adaptation maps for 5 sorghum and pearl millet varieties each made available and disseminated with associated capacity development to WCA partners

Achievement of Output Target:
50%

Adaptation maps for sorghum and pearl millet had been based solely on flowering dates so far. New experimentation has been initiated to include performance data in to the mapping process.

Participating Countries: Mali, Niger, Nigeria, Burkina Faso, Ghana

Participating Partners: IER, INERA, INRAN, LCRI, IA, SARI

Progress/Results:
A new multi-location variety evaluation trial has been conducted in 2009 to assess performance stability and genotype-by environment interactions: 20 pearl millet varieties, selected from the 2008 32-variety multi-location trial, were reevaluated at SerkinHaoussa and Sadore (both Niger), Nobere (Burkina Faso), Tominian (Mali), and Wa (Ghana). Furthermore, latitude dependency of the photoperiodic response was assessed including 30 sorghum and 30 pearl millet varieties grown in Samanko (Mali), Sadore (Niger) and Wa (Ghana). Existing pearl millet multi-location data from previous years are in an advanced stage of analysis. The new generation of adaptation maps shall include patterns of genotype-by-environment interaction as derived from these experimental data and modelled/extrapolated to sites with similar growing conditions.

Special Project Funding:
BMZ – Mobilizing Diversity, CODE-WA

BIG Haussmann

Output target 2010 3.2.1 Tools for farmer participatory recurrent selection tested for pearl millet and sorghum with partners with associated capacity development in different agro-ecologies

Pearl millet:

Achievement of Output Target:
75%.
Diversified pearl millet populations had been created in 2006 and two cycles of recurrent improvement were completed during 2007-08 using four different selection methods (on-farm mass selection, on-farm mass selection with parental control, and on-farm - and on-station full-sib family selection. The first field evaluation of progress from selection was completed during the rainy season 2009. Data analysis is underway. Initial results show weakly significant progress from selection for grain yield with all methods, and allow for identification of new experimental cultivars.

Participating Countries:
Niger, Nigeria, Mali

Participating Partners:
INRAN, LCRI, IER

Progress/Results:
As this McKnight Foundation-funded project is coming to an end in 2010, trials designed to assess the selection progress made so far in pearl millet were conducted on-farm (Tera, Falwel, Serkin Haoussa, Dioura, Aguie) and on-station (Sadore low-input, Sadore high-input, Maradi, Koporo) in the rainy season 2009. The results are expected to provide answers to the following questions:
-   Is the selection progress after two cycles of dynamic genepool management significant?
-   Which selection method produced the highest selection gain (on-farm mass selection; on-farm mass selection with parental control; on-farm full-sib (FS) selection; on-station FS selection; combined on-farm/on-station FS selection);
-   Which traits changed most in the selection process;
-   What are the advantages of the different methods – theoretically and practically?
-   Can populations selected by farmers at one site also adapt to other sites?
A MSc student from University of Hohenheim (Stefan Haffke) is currently analyzing the data and the thesis will be available in 2010.

Special Project Funding:
McKnight Foundation Germplasm project; IFAD-PROMISO

BIG Haussmann

Sorghum:

Achievement of Output Target:
75%.
Over the past years several schemes for recurrent selection have been tested with farmers. Several have resulted in new variety identifications, and the broadening of the genetic of breeding populations. The experiences gained have been used in training programs with NARS partners.

Participating Countries:
Mali, Burkina Faso, Nigeria, France

Participating Partners:
IER, INERA, IAR, ULPC, AOPP, UGPCA, AMSP, CIRAD

Progress/Results:

For all recurrent selection schemes the ms3 gene for genetic male sterility has been used. For diversifying existing populations crosses with local varieties, and/or varieties with specific desirable trait combinations were made. During the population recombination phase, mass selection for adaptation, and general preference was conducted, in farmers' fields, and on-station. Farmers mass selection proved to be very effective for eliminating undesirable traits and plant types from the population, adjusting the flowering period to a range that is preferred under target conditions by farmers. However, yield gains from this approach were limited, 10-20% over local controls, in Mali.

In Burkina Faso, and since 2007 in Mali, progeny trials were also conducted in farmers' fields, managed with support from a technically trained person. As these trials tend to be time consuming, especially during sowing time, farmers can not afford to sow them earlier than their food crop. These trials thus tend to be sown rather late, and not necessarily under good growing conditions. It remains to be evaluated what the effect of selection under such stress conditions will be for performance under more favorable conditions. Farmers have used the progeny trials also to identify lines for variety development.

NARS breeders were trained on the job, as a follow up to an earlier course. Statistical training was organized, to assist NARS with the analysis of such multi-location trials.

An article has been prepared during 2009 on the methods of participatory pedigree selection of sorghum in Burkina Faso with the following co-authors: Kirsten vom Brocke (CIRAD/ICRISAT), Gilles Trouche (CIRAD), Eva Weltzien (ICRISAT), Clarisse P. Barro-Kondombo (INERA), Eric Gozé (CIRAD) , Jacques Chantereau (CIRAD) .

The article focuses on the identification and understanding of farmers' selection criteria for sorghum varieties in the Centre-West region of Burkina Faso, and the correspondence of these criteria with agronomic observations. Preference rating and voting as well as participatory pedigree selection was initiated with 53 F3/F4 progenies using voting and rating exercises. Options for integrating farmers' selection expertise with that of the breeders' were examined during the early stages of the pedigree breeding program, which was carried out on-farm over three years (2001 to 2003) in two villages (Somé and Pouni). Whereas the breeders measured and analysed the agronomic data, the farmers evaluated a large number of progenies using their three most important selection criteria. Farmers' initial choices were consistent in the subsequent selection years, as indicated by the various selection exercises (voting). The farmers' methods for defining traits turned out to be more elaborate than the breeders' understanding of the traits. This was especially so for the criteria of grain quality and earliness. Farmers' definition of productivity, for instance, encompasses factors such as flour yield and stability across environments. The best correspondence was between farmers' productivity and measured grain yield. However, rating results between farmer groups was variable. Higher concordance was only registered when fewer farmer groups were evaluating the traits. Agreement between female and male ratings was especially weak for the grain quality traits. The article proposes strategies for future participatory breeding programs in sorghum, including the redefinition of selection criteria, as well as the choice and number of participating farmers and selection sites.

EW Rattunde, Kirsten vom Brocke and HFW Rattunde

Output target 2010 3.2.2 Two NARS empowered to breed groundnut varieties with multiple attributes especially drought tolerance

Achievement of Output Target:
75%
A wide range of genetic material supplied to enrich NARS genetic diversity from which to select adapted farmer-and market preferred varieties. Staff to manage the breeding programs received hands-on training and two are registered for a Masters degree in groundnut breeding.

Participating Countries:
Mali, Niger, Nigeria, Benin, Ghana, Cameroun, Chad, Togo

Participating Partners:
Institut d'Economie Rural (IER), Mali,
Institut de Recherche Agronomiques du Niger (INRAN), Niger,
Institute for Agricultural Research (IAR), Nigeria,

Progress/Results
The NARS breeding programs received diverse groundnut germplasm: A total of 397 advanced breeding lines were supplied to NARS collaborators in Niger (378) and Mali (19). These included lines with resistance to groundnut rosette and the vector aphid, tolerance to drought and aflatoxin contamination. Seven (7) regional nurseries involving 92 new breeding lines were distributed to five other countries (Benin, Cameroun, Ghana, Chad and Togo) in the region. It is expected that from this rich genetic base, farmer and market-preferred varieties will be identified for local production.

Capacity building (Infrastructure): Groundnut hand crossing facilities have been initiated at the Tarna station of INRAN in Niger after training of technicians at ICRISAT-Bamako. Minimum facilities for irrigation to ensure multiple generation advances within a year and nucleus seed production were provided to Niger. In Nigeria a groundnut rosette disease nursery was established to screen all the breeding material.

Capacity building (Human resources): 1 student registered at the University of Niamey for an Msc program. Two undergraduate students, Prosper Gassinta, of the Polytechnic of Katibougou Mali, and Youssouf Camara University Niamey Niger conducted their Bsc theses research in groundnut breeding. Mr. Mamary Traore of IER Mali completed a 4-months 'hands-on' training at ICRISAT Mali in groundnut breeding operations, and integrated crop management prior to the commencement of his course work at the university of Bamako. A 10-day intensive training workshop on groundnut breeding methodologies and techniques was held at ICRISAT-Bamako from 26 January to 6 February 2009 for research assistants and scientists. A total of 8 participants (2 from IER, Mali, 2 from INRAN Niger, 3 from IAR Nigeria and 1 from ICRISAT) attended the workshop. The course covered a range of topics organized in 10 modules. Two technical guides in groundnut breeding and PVS were prepared and are soft copies are available.

BR Ntare and F Waliyar

Output target 2010 3.2.3 Three high yielding, well adapted sorghum varieties with at least one trait adding value to the harvest (stover quality, sweet juicy stems, brewing quality) identified for dissemination to farmers in two countries in WCA

Achievement of Output Target:
50%
Sweet sorghum varieties, hybrids and germplasm have been tested at three locations in Mali, under a range of crop management regimes. The methods for sampling and processing samples have been improved. Many visitors and potential investors have been attracted. Seeds of sweet sorghum varieties and germplasm have been sent to Nigeria, Niger, Senegal, Liberia, and Burkina Faso.

Participating Countries:
Mali, Niger, and Senegal

Participating Partners:
INRAN, Niger and ISRA Senegal

Progress/Results:
Hybrid testing
Sweet sorghum hybrids tested at the Samanko station were mainly interesting for stem biomass. Nearly all hybrids had a clear green midrib and a good vegetative development. Height development was on average just above 3.00m (highest hybrids were 3.75m). In more than 35% of the hybrids lodging was observed. Flowering was in general too early for Sudanian zone conditions (heading started the first week of September and continued until the 26 of September) with the consequence of heavy grain mold infection. In view of the grain quality and the lodging problems of the new hybrids it could be concluded that the material will not be adapted to the conditions and needs of farmers in the Sudanian region of Mali. At the Cinzana research station breeders identified seven hybrids (among the 90 hybrids tested) with a preference score (breeder score) of good or average (ICSA 38 x SP 4495, ICSA 324 x SP 4495, ICSA 375 x SP 4495, ICSA 351 x SP 4511-2, ICSA 375 x SP 4511-2, ICSA 24005 x SP 4511-2, ICSA 480 x SP 4511-3. Brix values were between 11 and 12%. As in Samanko, the greatest concern was grain quality and grain discoloration (heavy grain mold infections).

Variety selection
At the Cinzana site 17 of the 50 progenies tested were selected by the IER breeders (six progenies had brix values equal or over 10%). Eleven of the 50 progenies tested at the Samanko station were retained for their relative good phenotypic appearance such as high stem biomass, stay green, panicle characteristics and grain quality (grain color, vitrosity, grain mold). The selected promising progenies were: 35768-1, 35865-2, 36875-1, 36012-4, 35579-1, 35894-2, 35816-2, 36197-1, 36298-1, 35742-4, 35803-1. Brix values of the selected progenies were between 10 and 15% at physiological maturity. An important selection criterion was grain vitrosity, which was very favorable in the selected entries.

At Samanko, fresh biomass of stripped stems ranged between 5 and 50t/ha (row spacing 0.3m x 0.75m, 2 plants/hill) and brix values at physiological maturity between 7,0 and 17,5% (mean 13.3%). Six entries of Ethiopian origin (IS accessions) had brix values over or equal 17%. All six had flowering times in the last week of September/first week of October and fresh stem yields (without leafs) between 17 and 37 t/ha. Entry IS23526 showed a good combination of biomass, brix and juice showed. Grain Yield performance (data observations not yet completed) was best in non-sweet control cultivars (Lata 3, Tiéblé) and varieties from Mali bred for the dual objective fodder/grain. These latter had brix values between 9 and 14% and relative week juice content compared to the local sweet sorghum types from Ethiopia and Mali. Seven sweet sorghum germplasm lines from Ethiopia had comparable high grain yield (as non sweet entries) in at least one replication.

At Cinzana station, mean brix values (8.6%) were considerably lower than at Samanko (14%). Mainly the dual purpose varieties from Mali had the lowest brix values between 3 and 8%. Lowest brix% values for Sweet sorghum types were 8% and highest 14%. These general low brix values at the Cinzana site were also observed in 2008. The germplasm accessions IS23569, IS23541 and IS23526 were among the sweetest entries. A good combination between juice and brix value was measured for IS23538 and IS23574. ICSV 93046 showed a promising combination of biomass, juice production and sugar. However agronomic preference was only scored as average and grain mold was noted. At Sotuba station, harvest was performed approx 4 weeks after physiological maturity. Brix values ranges between 11 and 21%. Among the best rated sweet sorghum types for agronomic performance score were IS23540 (red plant color) and IS23562.

Variety development
Altogether 53 crosses were performed by hand emasculation between Malien landraces, which have high potential for sugar yield and present and perfect adaptation to the environment of the region and varieties (elite lines and germplasm lines) based on Ethiopian origin with good sugar and grain yield potential. F1 seed was sown for F2 seed production at the off season plot. Germination was satisfactory in 80% of the progenies.

Hybrid development
Altogether 290 crosses were performed in 50 combinations. F1 lines will be evaluated for fertility aspects and performance during the rainy season 010.

Sweet sorghum crop management practices
Due to unusual late rains (01.11.09, 26mm), after the end of the actual rainy season the differentiation between the first and the second harvest date was difficult, especially for juice yield, which increased even after the 25 days delay of harvest. Mean brix values slightly increased from the first to the third harvest date from 14% to 16% and mean biomass (fresh stem weight without leafs) slightly decreased from 17t/ha to 13 t/ha. The fertilization does not seem to have an effect on mean brix values (analysis ongoing), which stayed constant at 15,1% across the two fertility levels. Mean juice yield increased for between 500 and 1000 l/ha when fertilizer was applied. Highest juice yields (up to 10 000 l/ha) were noted in the first and second harvest date for the varieties F221 (sweet sorghum landrace from Mali) and the variety 00-SB F5DT-427, an inbred line for fodder/grain production from IER. A closer analysis of all productivity related traits is underway with adjustments due to weak plant stand in some entries due to germination problems of the seed.

Kirsten vom Brocke

Output target 2011 3.2.1 At least two new breeding populations of groundnut with enhanced multiple attributes available for testing and selection by NARS

Achievement of Output Target:
25%

Germplasm with superior agronomic traits which can be used by plant breeders to develop high-yielding cultivars with broad adaptation identified.

Participating Countries:
Mali, Niger, and Senegal

Participating Partners:
INRAN, Niger and ISRA Senegal

Progress/Results:
The 53 F1s of the crosses made in the previous season were grown at ICRISAT Mali to produce the F2 seeds. Fifteen (15) new crosses involving farmer-and market preferred traits were completed to generate new populations with enhanced productivity.

Evaluate new germplasm sources for resistance to biotic traits. During the post rainy season 2008/09 we grew 268 accession of the reference collection under drought stress and non-stressed condition in a replicated trial under irrigation. One treatment received full irrigation and the second one received intermitted irrigations after flowering. The two treatments were in adjacent blocks. Measurements were taken for total biomass, pod yield and harvest index (HI) for pods calculated. The same set was sown in pots during February/ March 2009 to phenotype the lines for transpiration efficiency (TE) using the dry-down method. This consisted of exposing plants to progressive and drought stress 30 days after planting. In both field and pots experiments substantial variation among the accessions for yield, HI and TE were observed. From this trial it is expected to select suitable parents to develop populations for genotyping and phenotyping.

Foliar diseases: Specific diseases resistance nurseries and preliminary trials were conducted to identify superior breeding lines, or potential parents for future crosses. Seven preliminary trials were conducted. They included 416 F7-F8 derived from crosses made to combined at least two key traits. The traits of interest were grain yield, earliness, resistance to rosette disease and the vector aphid, tolerance to early leaf spots and limited fresh seed dormancy. The specific nurseries or trials addressed the following biotic stresses: Resistance to rosette and vector aphids, tolerance to aphids and early spot, tolerance to the rosette vector aphids, resistance to rosette, resistant to rosette and fresh seed dormancy. In each nursery or trials lines were selected that combined high grain yield, earliness with superior levels for resistance to the specific disease.

BR Ntare, H Falalou, V Vadez and F Waliyar

Output target 2011 3.2.2 Improved cycle of at least one sorghum broad-based population produced by random-mating superior progenies

Achievement of Output Target:
50%
New population crosses had been random mated, single superior plants selected in a range of target environments. During 2009 these S1 lines were evaluated for their adaptation and performance.

Participating Countries:
Mali, Burkina Faso

Participating Partners:
IER, INERA, UACT, UGPCA, ULPC, AOPP, AMSP

Progress/Results:
During the 2009 season a total of 1068 S1 lines originating from new population crosses, involving mostly parents of reduced height originating from partners, and farmers' breeding efforts were evaluated in at least two locations, with 2 reps per location. Conditions were good for evaluating susceptibility to grain mold, due to the late rains received. Materials were classified by flowering date, and internode length, for future evaluations for productivity, before recombining superior progenies.

E Weltzien, K vom Brocke, F Rattunde,
Chiaka Diallo, Clarisse Barro and Bocar Diallo

Output target 2011 3.2.3 At least 2 downy mildew resistant open pollinated varieties of pearl millet made available to partners with release relevant information

Achievement of Output Target:
75%.
One ICRSAT OPV is currently already used in resistance breeding programs in the region. In 2009, recurrent FS family selection for downy mildew resistance under field conditions in Sadore was conducted in nine promising population crosses. Best progenies will be recombined in the Jan 2010 off-season. A second cycle of selection may be undertaken at Bengou/Tara in 2010, to finalize the new cultivars with enhanced downy mildew resistance.

Participating Countries:
Niger, Mali

Participating Partners:
INRAN, IER

Progress/Results:
IER regularly uses the ICRISAT cultivar ICMV IS 92326 as source for downy mildew resistance; the respective seed is being provided by ICRISAT-Niger. At ICRISAT-Niger, full-sib (FS) trials for recurrent population improvement of DM resistance were conducted under artificial infestation at Sadore in rainy season 2009, involving 9 different elite diversified populations identified as superior in previous multi-location trials. Best FS families will be recombined in the Jan2010 off-season to form up to nine new experimental cultivars with improved downy mildew resistance. While repeatability in the 2009 field trials were usually reasonable (around 50%) for downy mildew resistance measures, differentiation among the full-sib families for head weight was less clearly pronounced, probably due to the late planting. Therefore, future downy mildew resistance field trials shall be shifted to a more Southern location, Bengou/Tara, where the natural downy mildew pressure is much higher. Also an off-season downy mildew screening nursery shall be established in Sadore in 2010 which will allow for even more efficient downy mildew resistance breeding.

Special Project Funding:
BMZ "Mobilizing regional diversity" until 2009; HOPE

<div align="right">BIG Haussmann, Moussa Sanogo and Seriba Katile</div>

Output target 2011 3.2.4 Refined adaptation maps for at least 10 sorghum and pearl millet varieties available for use by partners

Achievement of Output Target:
75%.

Participating Countries:
Niger, Mali, Burkina Faso Ghana

Participating Partners:
INRAN, IER, INERA, SARI

Progress/Results:
A new multi-location variety evaluation trial has been conducted in 2009 to assess performance stability and genotype-by environment interactions: 20 pearl millet varieties, selected from the 2008 32-variety multi-location trial, were reevaluated at Serkin Haoussa and Sadore (both Niger), Nobere (Burkina Faso), Tominian (Mali), and Wa (Ghana). Furthermore, latitude dependency of the photoperiodic response was assessed including 30 sorghum and 30 pearl millet varieties grown in Samanko (Mali), Sadore (Niger) and Wa (Ghana). Existing pearl millet multi-location data from previous years are in an advanced stage of analysis. The new generation of adaptation maps shall include patterns of genotype-by-environment interaction as derived from these experimental data and modeled/extrapolated to sites with similar growing conditions.

Special Project Funding:
CODE-WA

<div align="right">PCS Traore, BIG Haussmann, A Sacko and E Weltzien</div>

Output target 2011 3.2.5 Understanding of dry land cereal pest dynamics enhanced for at least two priority species across WCA, and used in adaptive IGNRM research targeting at least two countries

Cereal Insects Pests:

Achievement of Output Target:
50%
Disappointing results were obtained on sorghum head-bugs ecology and management prospects, on the other hand, promising collaborations were established for further studies on agro-ecological management of this pest;

Significant results (although "negative" in terms of management prospects) were obtained on millet stem borers; Promising results on the effect of these management techniques on millet head pests are expected from collected data whose analysis is underway.

Participating Countries:
Niger

Participating Partners*:*
INRAN (Hame Abdou Kadi Kadi; Ibrahim Baoua; Salami Issoufou)
University Abdou Moumouni, Niamey, Niger (Doumma Ali; Rabo Younoussou)
France: CIRAD/DAP (Monique Deu)
USA: Nebraska State University (Ousmane Youm)
West Texas A&M University (Bonnie Pendleton)

Progress/Results:
In a trial on management of crop residues for reducing impact of millet pests, all treatments and observations were applied/carried out as per planned schedule. Main groups of macrofauna recorded were coleopteron larvae (particularly wire worms and white grubs: mainly Rhinyptia) and diapausing Heliocheilus pupae in the soil, along with some beetle adults, some dipterous larvae, orthoptera, ants and termites, arachnidae and centipedes. In the case of termites, there was no effect of treatments but a strong block effect. Given the mixed results of the termite studies, another location will be sought on the Sadore campus with a more uniform pressure. Other analyses of soil macrofauna density, biomass and diversity are underway.

A preliminary survey was conducted at the INRAN research stations of Konni and Kollo in view of identifying of a second site for millet residue management studies under Activity 3.2, to be monitored by Mr Hame Kadi Kadi. At Kollo, on an agronomical trial comparing millet-millet vs millet-cowpea rotation, neither Millet Stem Borer (MSB) Coniesta ignefusalis nor head-beetle incidence were high nor significantly different between the two treatments, why there was a tendency (10%) for Heliocheilus (1.9 +1.1 mines per head in the millet-cowpea rotation, compared with 0.7+0.4 in the millet-millet rotation). At Konni, on a similar trial but with lower fertilizer application, there were no differences for Heliocheilus and head-beetle incidences, while there was a tendency (10%) for Coniesta (1.5+0.4 holes per stem in the millet-millet rotation compared with 0.6 +0.7 in the millet-cowpea rotation). In any case, none of the two locations showed any comparative advantage with Sadore (same level of Coniesta infestation and not higher level of head pest infestation). Another spot will have to be sought (in the Maradi region?), preferably in a fenced research station given studies on crop residues to be conducted.

In this experiment a significant effect of the treatments applied was found on the MSB Coniesta, namely that with >70 diapausing larvae/m², the treatment with millet stems lodged 4 months after harvest, supposedly the most effective against wind erosion, was also the most favorable to Coniesta carry-over (diapausing larvae population ranging from 18 to 34 larvae/m² on all other three treatments: resp. with stems lodged at the time of harvest, kept upright al through, and lodged 2 months after harvest). Dismissal of Andropogon grass as a potential trap crop for millet stem borer Coniesta management was confirmed after a 2nd year of observations, since bored stem incidence in the Andropogon hedge bordering the trial plots was significantly lower than on millet, with no C. ignefusalis larva recovered, compared to 1.5 larvae per stem in millet in 2009 (percent damaged stems being respectively 25.6% on Andropogon vs 67.6% on millet).

Special Project Funding:
HOPE Project funded by BMGF

<div align="right">A Ratnadass</div>

IGNRM for Striga management:

Achievement of Output Target:
25%
Cluster-based farmer field schools were initiated in one new region, Mopti in Mali, and continued in Nigeria, and Mali. Evaluations of farmer field schools were carried out in Niger, Mali and Nigeria. Field collections of Striga seed, and plant material were carried out in Mali and Senegal. On station experiments for evaluating treatment combinations were carried out in Mali.

Participating Countries:
Mali, Nigeria, Niger, Senegal

Participating Partners:
Mali: Institut d'Economie Rurale (IER), Union des Agriculteurs de Cercle de Tominian (UACT), Aga Khan Foundation (AKF)
Nigeria: Institute of Agricultural Research (IAR), Lake Chad Research Institute (LCRI), Community Based Agricultural and Rural Development Program (CBARDP)
Niger: Institut National de Recherche Agronomique du Niger (INRAN), Projet de Promotion de l'Initiative Locale pour le Développement à Aguié (PPILDA)
Sénégal: Institut Sénégalais de Recherches Agricoles (ISRA), Agence Nationale de Conseil Agricole et Rural (ANCAR)

Progress/Results:
Diagnostic village interviews were conducted in 10 villages in Mali for determination of main crops, crop production constraints and the relative importance of *S. hermonthica*. Within 11 clusterbased farmer field schools participatory on-farm trials were implemented in Nigeria (30), Mali (24), and Niger (3), involving the training of at least 1140 farmers on integrated Striga and soil fertility management (ISSFM) in 2009.

22 populations of *Striga hermonthica* were sampled in Mali (12), Senegal (7) and Niger (3) with 40 different individuals each for determination of genetic diversity. This work was carried in collaborative with the University of Georgia, USA. On-station assessment of the interaction between Striga infestation density, fertilizer microdose application and host resistance and their effects on sorghum yield and Striga population dynamics was conducted for two years. Overall analysis of results is in progress.

Special Project Funding:
IFAD-TAG817, PROMISO. Funding: IFAD-Technical assistance grant.
Geo-ecological and agronomic drivers of *Striga hermonthica* genetic diversity and population density. Funding: USAID-linkage grant.
Improving food security and increasing incomes from sorghum and pearl millet production systems in the Mopti region in Mali, Funding: Aga Khan Foundation.

<div align="right">Tom van Mourik, M Kayentao, I Karimou,
M Maina, B Tanimu and E Weltzien</div>

Output 3: Crop management, Aspergillus flavus resistant groundnut varieties and post-harvest technologies to reduce aflatoxin contamination in food and feed products, as well as micronutrient rich cereal varieties and processing techniques to improve bio-availability developed, tested and made available to partners with new knowledge in the SAT of WCA

Output target 2009 3.3.1 Early adoption of crop management practices to reduce Aflatoxin contamination in Mali documented

Achievement of Output Target:
100%
Aflatoxin contamination is an unknown phenomenon in the farming systems of the study region. Farmers as producers of groundnut and consumers of groundnut products, are not aware of the aflatoxin and its effects on people and animals, and hence do not perceive aflatoxin contamination as a problem. Results from surveys show that there is still limited awareness about Aflatoxin contamination and limited adoption of management practices to minimize contamination is very low.

Participating Countries:
Mali and Ghana

Participating Partners:
IER and SARI, Université de Sherbrooke, Canada

Progress/Results
Farmers' knowledge about Aflatoxin contamination problem in groundnut is limited. Crop management practices used by farmers are conditioned by various socio-economic factors prevailing in the region. The adoption of improved production and post-harvest technologies evaluated by farmers was evaluated in Kolokani district of Mali. An aflatoxin awareness survey was therefore conducted to provide household level quantitative and qualitative data on smallholder groundnut producers of Ghana and Mali, including data on aflatoxin awareness and management. The data would also serve as a baseline for further monitoring, assessment and mitigation of aflatoxin risks in smallholder groundnut systems of West Africa.

The survey was conducted in four districts covering a range of agro-climatic, ethno-linguistic, edaphic and ecologic conditions typical of the groundnut growing belt of West Africa, for a total number of 350 surveyed households. The surveyed districts were: Dioïla, Mali (50 households in 5 villages), Kolokani, Mali (100 households in 10 villages), Sissala, Ghana (100 households in 10 villages), Wa, Ghana (100 households in 10 villages). The survey used questionnaires with closed and open-ended questions covering socio-economics status at producer and household levels, aflatoxin awareness and perception of produce quality, crop management practices (for 2008 cropping season), storage methods, consumption patterns, usage frequency for feed, linkages with farmer organizations, estimated sale losses, and (for a subset of 50 households in Kolokani district only) diffusion pathways for agronomic management of aflatoxin.

Farmers' perceptions and awareness of the importance of quality of groundnut and the risks associated with aflatoxin varied among the villages surveyed. In Mali about 55% of the respondents had heard about Aflatoxin while only 6% in the Ghana villages heard about it. The awareness about effects of aflatoxin on human and animal health, 73% was much higher in Ghana (> 90% of the respondents) than in Mali. Overall, less than 30% of the respondents in the survey areas were familiar with the causal agent- *Aspergillus flalvus*

Results on diffusion production and postharvest technologies to minimize aflatoxin contamination (for a subset of 50 households in Kolokani) revealed that 32% of the farmers had knowledge of at least one aflatoxin management practice.

This study shows that there is some level of awareness of aflatoxin and perception about its effects on human and animal health. This is a result of the activities conducted in the Kolokani region during the groundnut seed project (2003-2007). However, farmers are still oblivious to the fact their current production and post-harvesting practices are likely to increase chances of aflatoxin contamination. They do not perceive any economic risks in producing a groundnut crop that may be contaminated, since neither the groundnut prices are influenced due to aflatoxin contamination nor are there any market restrictions on its sale. It is essential to understand the socio-economic context and identify factors constraining the adoption of improved practices in the districts surveyed

Special Project Funding:
CCCLF project and BMGF (TLII)

PSC Traore, BR Ntare, J Ndjeunga and F Waliyar

Output target 2010 3.3.2 ELISA testing lab set up at ICRISAT-Bamako

Achievement of Output Target:
100%
The aflatoxin lab at Samanko is operational. A minimum of 2000 samples is analyzed every month.

Participating Countries:
Mali

Participating Partners:
IER

Progress/Results
A large number of samples from the groundnut program are routinely being screened for Aflatoxin contamination using the ELISA kit. The lab is also capable of analyzing foods samples from markets.

Special Project Funding
BGMF-IFPRI, TLII

F Waliyar

Output target 2011 3.3.1 2--3 Farmer-and market preferred groundnut varieties tolerant to aflatoxin contamination identified for dissemination by at least three NARS in WCA

Achievement of Output Target:
50 %
Advanced breeding lines with enhanced tolerance to aflatoxin contamination made available to NARS for evaluation.

Participating Countries:
Benin, Ghana, Mali and Niger

Participating Partners:
INRAB, CRI, IER and INRAN

Progress/Results:
On-station evaluation of advanced breeding lines for tolerance to aflatoxin contamination in Mali and Niger

A trial consisting of 19 advanced breeding lines tolerant to aflatoxin contamination along with resistant (55-437 and JL11) and susceptible (JL 24) checks was conducted in Mali (Kayes and Samanko) and Niger (Sadore, Maradi and Bengou) to determine the level of aflatoxin contamination as well as yield performance. The level of aflatoxin contamination varied among locations with the lowest aflatoxin contents recorded at Maradi and Bengou. Sadore, considered as hot spot for aflatoxin screening recorded the highest aflatoxin content of 1624 on the susceptible check compared to less that 10ppb of most of the test lines. Only one test line recorded 693 ppb, while the resistant checks recorded less than 1 ppb in the Niger locations. At Samanko, only 2 test lines recorded aflatoxin content of more than 20 ppb. The resistant check had 1.23 ppb while the susceptible check recorded 899 ppb. The highest yielding lines with low level of aflatoxin contamination (< 5ppb) were: ICGV 92302, ICGV 03315 and ICGV 03323, ICGV 94379, ICGV 93305, ICGV 91279, ICGV 94379, ICGV 91324, ICGV 91284, ICGV 91315, ICGV 91283, ICGV 92302 and ICGV 89104. The results from this trial show that there are high-yielding varieties with high levels of tolerance to aflatoxin contamination. These lines will contribute significantly to the integrated management of aflatoxin contamination.

On-farm evaluation of advanced breeding lines for tolerance to Aflatoxin contamination in Mali and Niger.
In Mali, 18 groundnut genotypes along with 2 controls - 55-437 (resistant check), JL 24 (susceptible check) - were grown by two farmers in Kolokani in order to evaluate their resistance to aflatoxin under farmer conditions. The genotypes were arranged in Randomized Blocks Design (RBD) with 2 repetitions with plots of 100 m^2 (10 m x 10 m). The aflatoxin content of the test lines varied from 2.94 ppb to 32.08 ppb. The resistant check had 4.89 ppb while the susceptible check had 989 ppb. Overall 12 genotypes recorded less than 10 ppb. ICGV 91279 was the best with 2.94 ppb against 4.89 ppb for the resistant control 55-437. Genotypes ICGV 93305, ICGV 89104 and ICGV 89104 showed ≤ 5 ppb aflatoxin. JL 24 showed the highest level of aflatoxin with 988 ppb. Pod yields were generally low and varied from 0.52 t/ha (ICGV 91278) and 0.85 t/ha (ICGV 91324)

In Niger, 15 groundnut genotypes and 1 resistant control (55-437) were evaluated by 15 farmers in the Maradi region. Each farmer received 6 varieties. Each variety was sown in plats of 64 m2 and each farmer was considered as a replicate. Eight genotypes recorded less than 5 ppb and the remaining genotypes had less than 10 ppb aflatoxin compared to the resistant control 55-437 which recorded 10.467 ppb. All the genotypes recorded ≤ 10 % seed infection by *Aspergillus flavus*. The most resistant genotypes were ICGV 92302 (2.22%), ICGV 93328 (3.11%), ICGV 91279 (3.33%), ICGV 91317 (3.56%), ICGV 89104 (4%) and ICGV 91324 (4%) against 4.148% for the resistant control. The result from this trial validate the tolerance of the test lines under farmer management conditions.

BR Ntare and F Waliyar

Output target 2011 3.3.2 Mini-core Groundnut collection phenotyped for tolerance to A. flavus and aflatoxin contamination

Achievement of Output Target:
90%
New sources of high levels of tolerance to aflatoxin contaminated identified. These will be used to develop new breeding populations with enhanced tolerance to Aflatoxin contamination.

Participating Countries:
Niger

Participating Partners:
None

Progress/Results:
Screening of the mini-core collection
A trial consisting of 166 groundnut mini-core collection along with 2 resistant controls (55-437 and J11) and 2 susceptible controls (Fleur 11 and JL 24) was conducted at Sadoré in 2009 crop season to evaluate their resistance to *A. flavus infection* and aflatoxin contamination.
The experimental design was a Randomized Blocks Design (RBD) with 3 repetitions with plot size of 4 lines of 4 m long with 10 cm interval within and 50 cm between the lines.

The level of aflatoxin varied from 0.9 to 1052.7 ppb. Twenty four (24) accessions showed high levels of resistance with ≤4 ppb aflatoxin while the best available resistant lines (J11 and 55-437) showed 5.1 and 7.1 ppb respectively. The susceptible checks showed very high levels of aflatoxin content- 827 ppb for Fleur 11 and 1052.7 ppb for JL24. ICGs 1415, 5195, 14630 6703 3585 8490, 6888 were the most resistant with ≤2 ppb aflatoxin. These results confirm those of 2008 crop season. These accessions will be used to generate new breeding populations with enhanced tolerance to aflatoxin contamination.

Seed infection by *Apergillus flavus* varied from 1.5 to 68%. Among the lines with low levels of aflatoxin only 2 lines showed less than 10% seed infection. In total 36 six genotypes showed ≤10 % seed infection. ICG 11249, ICG 4343, ICG 332, ICG163, ICG 12879, ICG 1274, ICG 3343, ICG 14466, ICG 4670 and ICG 532 were the best with seed infection varying from 1.48% to 4.44%. There is no correlation between seed infection and aflatoxin contamination. Several genotypes with high levels of resistance to aflatoxin showed ≥10% seed infections. Other lines with higher levels of aflatoxin showed lower level of seed infection.

Pods yields varied from 0.204 t/ha (ICG 11475) to 2.275 t/ha (ICG 11249) with 42 genotypes recording more than 1.5 t/ha. The most productive genotypes were ICG 11249 (2.275 t/ha), ICG 4684 (2.222 t/ha), ICG 3584(2.079 t/ha), ICG 1519 (2.05 t/ha) and ICG 12988 (2.025 t/ha). Haulm yields varied between 0.5 t/ha (ICG 5286) and 6.1 t/ha (ICG 76) (Table 7). More than half of the tested genotypes yielded more than 3 t/ha. But the most productive genotypes were ICG 76 with 6.1 t/ha followed by ICG 2777 (5.7 t/ha), ICG 4750 (5.5 t/ha), ICG 6813 (5.5 t/ha), ICG 163 (5.3 t/ha), ICG 6703 (5.3 t/ha), ICG 4389 (5.3 t/ha), ICG 6201 (5.1 t/ha), ICG 11687 (5.1 t/ha) and ICG 5663 (5.1 t/ha)

Phenotyping of the groundnut reference collection for adaptation to drought stress and related traits
A reference collection of 268 genotypes of groundnut along with 9 farmer-preferred varieties was evaluated under drought conditions. The experiment was conducted during late planting rainy season (September-December 2008) and dry season (February-June 2009). The entries were planted in 6 replicated plots arranged in randomised bloc design. In two adjacent blocks one block receives full irrigation and the

second one is stressed by skipping the irrigation. After harvest, seeds of stressed plants were collected; ground to flour and aflatoxin was estimated using ELISA method.

Analyzed data of late planting rainy season experiment revealed high significant (P<0.001) differences among accessions. The aflatoxin content (AFL) ranged from 1.16 to 680.4 ppb. The results showed that, under drought conditions, the accessions ICG 5663, ICG 4746, ICG 9905, ICG 10384, ICG 11322, ICG 311 and ICG 1834, with AFL≤ 5 ppb, were resistant while the accessions ICG 8253, ICG 7867, ICGV 02022, CG 15309, ICG 111, ICGV 02148, ICG 5609, ICG 11515, ICG 3027, ICG 5327, ICG 14106, ICG 875, ICG 14834, ICG 10010 and ICG 5494, with AFL≤ 10 ppb, were tolerant. The remaining entries were sensitive to aflatoxin contamination. None of the resistant or tolerant accessions is farmers preferred variety. Data analysis of dry season 2009 trial and late planting rainy season 2009 trial are underway to validate these results.

Special Project Funding:
TLI (BMGF)

<div align="right">F Waliyar, H Falalou and V Vadez</div>

Output target 2011 3.3.3 Two sorghum and pearl millet varieties with increased iron and zinc content, and low content of anti-nutritional factors available for cultivation in at least two countries in WCA

Pearl millet:

Achievement of Output Target:
50%.
First cycle of recurrent selection in three diversified pearl millet populations completed. Need to perform second selection cycle to further enhance Fe/Zn grain contents. Grain Fe/Zn analysis is difficult, failed to be done locally in a reliable manner; analysis in service laboratory takes a lot of time.

Participating Countries:
Niger, Germany

Participating Partners:
University of Hohenheim (2009) for grain analyses.

Progress/Results:
Grain samples of 432 Full-sib families (FS) x 2 replications (FS selected for above-average agronomic performance from 2008 FS trials conducted at Lossa and Sadore) were sent to University of Hohenheim for Fe/Zn analysis. Data was received only in December 2009. First data analysis revealed excellent data quality and high heritability estimates for Fe (h^2=0.68) and Zn (h^2=0.63) in the FS population derived from the cross ICMV IS 89305 x GB8735. Further data analysis is underway. Best FS with highest Fe/Zn contents in the grain will be recombined in the Jan 2010 off-season.

Special Project Funding:
Harvest Plus CP until 2008; BMZ "Mobilizing regional diversity" in 2009; HOPE

<div align="right">BIG Haussmann</div>

Sorghum:

Achievement of Output Target:
50%.
First cycle of recurrent selection in three diversified pearl millet populations completed. Need to perform second selection cycle to further enhance Fe/Zn grain contents. Grain Fe/Zn analysis is difficult, failed to be done locally in a reliable manner; analysis in service laboratory takes a lot of time.

Participating Countries:
Mali, Burkina Faso, Switzerland, Netherlands, France

Participating Partners:
IER, Mali, Helen Keller International Mali, Department de Technology Alimantaires, IRSAT, Burkina Faso; University of Wageningen, ETH Zuerich, IRD, Montpellier, France; ICRISAT India for analyses.

Progress/Results:
During 2009 we received data on iron and zinc content of 70 sorghum varieties tested in 2 stations under high and low soil fertility conditions. Results indicated significant varietal differences, with some impact of the testing conditions: low fertility reduces mineral concentrations. We conducted joint data analyses of trials from previous two years, to conclude, that high FE and Zn concentrations are related to good processing qualities, as preferred in Mali: vitreous grain, that decorticates easily, with low decortication losses.

The analysis of Fe, Zn concentration in trials conducted on-farm, under a wider variety of growing conditions confirmed impact of growing conditions on general mineral concentrations. Varietal differences were significant. Varieties from the guinea race tended to have higher concentrations. Many of the caudatum race or intermediate race varieties had very low levels of mineral concentrations.

An overall state of art report was written, to combine all the experiences and results with Fe and Zn analysis for sorghum. This highlighted the need for a better quantification of the phytate levels, as well as other antinutritional factors, that interfere possibly with iron absorption in the human body. Trials were initiated in collaboration with ETH Zuerich to quantify polyphenol levels, as well as tannins specifically.

Trials were initiated in collaboration with DTA and IRD to quantify bioavailability of Fe in dishes prepared with high Fe pearl millet varieties in Burkina Faso.

Output 4: High quality seed of adapted, released varieties of sorghum, pearl millet and groundnut accessible and affordable to small scale farmers in a timely manner through networks of agro-input dealers, seed entrepreneurs and breeders, both public and private by focusing on sustainable breeder and foundation seed production and creating an enabling agricultural environment for regional seed trade in West Africa

Output target 2010 3.4.1 Improved agricultural enabling environment established for marketing high quality seed of sorghum, millet groundnut, etc. between West African Countries

Achievement of Output Target:
25%

During 2009 the improvement of agricultural enabling environment for marketing quality seed between West African countries was limited due to the fact that USAID West Africa decided to hand over the financial support of this component to CILSS/INSAH. The little achievement was the adoption of the seed policy framework in Mali, (awaiting the seed law), the analysis and modification of existing national laws and regulations for conformity with approved regional seed regulation, the organization of national workshop of science base quarantine pest list in Cote d'Ivoire, Mali and Gambia. The development by SSC/ISU of a new software for the web base catalogue to be installed on the INSAH server.

Participating Countries:
As the financial founding of these activities is managed by INSAH/CILSS the countries involved in the 2009 enabling environment interventions were Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Mali, Niger and Nigeria (having good collaboration with INSAH)

Participating Partners:
NARES, CILSS/INSAH; CNFA, SSC/ISU and USAID Mali.

Progress/Results:
In April 2009 USAID WA signed with CILSS the implementing letter (IL) 12 related to an existing agreement N° 624-008-06-01 dated Sept 2006 between CILSS and USAID. With that new arrangement all the Seeds Project planned activities on the enabling environment were transferred to CILSS/INSAH. Under this new arrangement national workshops on quarantine pest for seed import export were organized in Cote d'Ivoire in October and Mani in November to clean the country pest list following the recommendation of the regional workshop on the same subject. Draft seed laws were established for Mali and Ghana in conformity with the regional approved seed regulation. The same work is been done by working group or consultancy in Benin, Niger, Nigeria, Gambia and Burkina Faso with financial support from INSAH and technical assistance from ISU. It is important to mention that the African Union has established link with the WASA Seed Project on "Institutional Arrangements and Implementation Strategy for the African Union Seed and Biotechnology Programme (ASBP)". This program among other planned to (i) promote effective seed production systems (ii) enhance development of quality assurance systems with more effective stakeholder contributions (iii) Promote seed marketing and distribution and (iv) develop improved disaster preparedness and response to seed insecurity.

Special Project funding:
The enabling environment improvement activities were fully funded by USAID through Institut du Sahel.

N Maroya

Output target 2011 3.4.1 Enhanced availability of foundation seed to satisfy requests from certified seed producers, especially with linkages to product markets in Ghana, Mali, Niger and Nigeria

Achievement of Output Target:
50%

Participating Countries:
Mali, Niger, Nigeria

Participating Partners:
IER, INRAN, IAR

Progress/Results:
For sorghum IER has been contracted by the WASA Seeds project to produce foundation seed of released sorghum, pearl millet, rice, maize and groundnut varieties. ICRISAT has produced breeders and foundation seed of newly released, and other sorghum and pearl millet varieties for sale to professional seed producers. IAR has been contracted by WASA Seeds to produce foundation seed of released sorghum and maize varieties.

Special Project funding:
USIAD Seeds project, McKnight Foundation Seed project

E Lin

Output target 2011 3.4.2 Seed dissemination channels assessed in at least one country in WCA

Achievement of Output Target:
25%
In Mali one study was undertaken to assess the role of seed networks for dissemination of new sorghum varieties. Another study examined the options for supporting farmer cooperatives for more effective seed marketing and dissemination. A specific study focused on the

documentation of varietal sorghum and millet diversity and its evolution as well as the diffusion of varieties disseminated by ICRISAT since 2002 in two different villages in Mali. Further the effect on varietal properties of farmers' different ways of auto producing a modern sorghum variety in their production systems was studied.

Participating Countries:
Mali, Niger, Burkina Faso

Participating Partners:
IER, INERA, INRAN, ULPC, AOPP, UGPCA, AMSP, Mooriben, Fuma Gaskya

Progress/Results:
This research was carried out within the project called IMAS, "Impact of the Methods of Access to Seeds on the diversity of genetic resources in agriculture", lead by the CIRAD, in collaboration with IER. The overall aim of the project is to contribute to optimum use and maintenance of agro-biodiversity, by identifying new ways of managing varietal diversity based on the interaction between farmer, trader and institutional seed systems, on different scales.

Two villages were identified as study sites: Magnambougou in the Dioila cercle [700mm] and Gonsolo in the Mandé district [900mm] regions). Surveys using semi-formal interviews with all production units in the two villages were undertaken .Questions addressed the number of varieties presently cultivated and in the last 20 years, the seed sources and quantities used, seed exchange and variety characteristics. Semi-formal interview were carried out in order to identify farmers who autoproduce the variety Soumba (CIRAD406) since at least two generations on their farm. Six seed lots were collected and sown together with two control seed lots (foundation seed/ICRISAT and certified seed/ULPC) at the Samanko station. Besides agro-morphological observations the number of off-types were counted in each plot. Additionally off-types were counted directly in farmers' fields (among at least 100 hills in three different parts of the field) in the fields sown with the 2008 seed stocks. Samples of 30 panicles were taken of each seed stock in order to analyze the level of heterogeneity by means of molecular markers in the following project years.

Varietal diversity
Sorghum was grown on approx 118ha and millet on 84ha in Magnambougou in 2008. Most of the UPs are growing both species. In Gonsolo sorghum was the dominant species in 2008 and in the last decade with approx 90ha in 2008. Magnambougou interviews showed that sorghum is produced for family consumption and commercialization as a source of income . Millet is grown mainly for family consumption and culinary reasons as well as a wide range of diverse and individual other reasons (e.g. health, tradition, ease of processing). Millet is grown on the more poor soils. Farmers in Magnambougou who only grow millet do so because it can grow extensively, without mechanization.

In Magnambougou ten sorghum varieties and six millet varieties (or variety groups) were cultivated by the 22 UPs in 2008. In Gonsolo the 22 UPs cultivated eleven sorghum and only one millet variety. The latter was used by only one family. The most frequently grown varieties occupy also the largest field area and are shorter duration varieties. This variety type is preferred for yield security in both villages.

It has been noted that in Magnambougou varietal for sorghum increased in the last five years. Farmers are looking for more varietal options of cereals, due to the decline or abandon of cotton production in the area. In Gonsolo, where cotton production was less pronounced, the number of varieties cultivated in the last years was more stable. Other diverse reasons have been noted for the abandon of other, less frequently grown varieties. It was also noted that a specific variety (Kendé) has been mainly used in the past for growing on fields which have been freshly turned over from bushland. Demographic pressure, with less or no fellow periods in the rotations may be a reason that this variety hasn't been used in the past years.

Variety exchange of introduced varieties
Variety exchange was studied closer for two varieties, namely the modern variety Soumba at Magnambougou and the introduced germplasm accession Soumalemba at Gonsolo. Between 2005 and 2008 exchange of the variety Soumba is relatively frequent between the farmers. The gift (giving seed as a present) is the most frequent way which constitutes 60% of all exchange activities in this period. Exchange against some other seed (e.g. millet) accounted for 14% of exchange activities and purchasing counted for 26% of all cases. This relatively high value is due to the seed commercialization activities of the farmer-union ULPC in the village. The most frequent exchange way for Soumalemba in Gonsolo was equally the gift (59%) followed by exchange (36%) and only 5% of the exchanges were purchase, which was one time within 2001 and 2007.

Effect of farmers' auto-production
Autoproduction of seed is still the most common way to secure a seed stock. Different methods are used for keeping seed for sowing. Farmers producing Soumba used panicle selection of preferred and typical panicles in the field, elimination of off-types in the field before harvest, and no selection or purification at all. The effects of these practices were studied in a field trial. This indicated that at least three farmer seed stocks had significant higher percentage of off-types (5 to 20%) than the control cultivars (1 to 2%). The different number of off-types, however, did not significantly affect the mean height or the panicle length of the variety compared to the controls. Mean height ranged from 242cm to 268cm, with both extremes having only a minor count of off-types (2 and 0%, respectively). No significant differences in days to 50% heading has been observed among the different seed stocks. The direct count in farmers' fields of the same seed stocks but sown by farmers in their usual production systems came to similar conclusions. Further analysis needs to be undertaken to better understand the effects of the different seed selection methods on the seed stock properties. Grain yield components need yet to be analyzed.

The studies on seed networks and options for improving the capacity of farmer cooperatives for seed commercialization still need to be finalized.

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MTP Project 4: **Producing more and better food from staple cereals (sorghum and millets) and legumes (groundnuts, chickpea and pigeonpea) at lower cost in the eastern and southern African (ESA) SAT through genetic improvement**

Project Coordinator: Mary A Mgonja

Highlights for 2009

Project summary:
Project 4 contributes to the overall goal of achieving sustainable food, nutrition and income security of farm families in ESA and is responding to CGIAR System Priorities i) 2A to increase yield and considering pro- poor traits (pests, diseases and Striga), ii) 2B abiotic stresses (drought) and (iii) 2C on nutritional quality of sorghum, pearl and finger millet through bio-fortification as well as on food safety issues associated with aflatoxins in groundnut. The project has five outputs designed around the 3 SP areas but linked with other SP and projects. Highlights of 2009 progress by outputs, key IPGs, outcomes and impacts are highlighted:

Output 4.1: Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented. This output focuses on strengthening the efficiency of breeding and cultivar evaluation while conserving and making maximum use of the natural genetic resource base (linked to project 2). Regionally-based task networks integrate farmer participation and include i) regional evaluation teams across the ESA region that are focusing on addressing constraints of drought through sorghum variety and hybrid evaluation, midge and sweet sorghum as well as constraints expressed in sub-humid environments and on finger millet evaluation ii) a pigeon pea team in Tanzania and Malawi that was supplied with high yielding early, medium and long duration genotypes for evaluation and seed increase. iii) introduction of Desi and Kabuli chickpea genotypes with resistance to *Fusarium* wilt for further evaluation in Kenya and Tanzania. Breeding networks emerged from collaborative development and implementation of regionally oriented projects such as Tropical Legumes II and HOPE for dryland cereals.

Output 4.2 Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences. Genetically diverse breeding populations were developed and advanced for sharing with partners for further selection e.g. sorghum lines that are resistant to striga (developed using MAS), midge, stem borers and leaf diseases; pigeon peas with resistance to *Fusarium* wilt, groundnuts that resist early and late leaf spots, rosette and aflatoxin contamination and improved sweet sorghum for bio-ethanol. Hybrids and OPVs were tested to provide farmers with more options. Capacity building was provided on need basis e.g. on marker-assisted breeding as well as seed production to support dissemination of released varieties and seed of various categories that were shared through signing of SMTAs.

Output 4.3 New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, specific abiotic stress tolerant varieties and associated knowledge and capacity development. Drought is considered to be the primary cause of yield reductions for crops in Sub-Saharan Africa. Early maturing varieties that escape terminal drought have been developed and introgression of Stay-green (Sg) into farmer varieties is on-going as a mechanism to confer drought tolerance. Stay-green QTL from two ICRISAT donor parents (B35 and E36-1) were introgressed through MAB into 4 farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale and advanced BC3F3 in 2009. Phenotyping of these lines as well as of improved lines with introgressed Sg QTL from India will be done in 2010 in Ethiopia to evaluate the effect of the stay-green QTL in Africa. This was not achieved in 2009 due to severe droughts during both cropping seasons.

Output 4.4 Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified germplasm with enhanced micronutrient levels available for evaluation. The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment. The consequence of the transgene movement will however depend on the nature of the transgenic trait. The hybrid fitness study demonstrated that hybrids between wild and cultivated sorghum could survive under natural conditions but may not necessarily have an advantage over wild sorghum. Results from another gene flow study suggested that the deployment of GM sorghum in Kenya and Mali will lead to the asymmetrical movement and long-term persistence of transgenes into wild and weedy populations within and around sorghum fields.

Output: 4.5 Technological options and knowledge to reduce groundnut aflatoxin contamination.
Aflatoxins contaminate groundnuts and other agricultural commodities. Management is difficulty due to lack of awareness, environmental conditions and farming practices. Farmer Field Schools (FFS) are now successfully used in ESA to promote aflatoxin management practices on farmers' fields. Awareness of the problem is also easily discussed and understood using the informal learning nature of FFS.

IPGs: Genetically diverse and improved germplasm, parental lines and varieties, breeding networks, new tools e.g. for aflatoxin diagnostics, traits discoveries and strengthened capacity.

Outcome: Partners in breeding networks i) share responsibilities and products ii) have the capacity to use and integrate new and more precise tools iii) have access to quality seed of improved high yielding and nutritious germplasm for further testing iii) have access to mycotoxin diagnostic tools and iv) have improved knowledge on gene flow and GM deployment.

Impact: Improved efficiency in breeding, better access to quality seed, nutritious and safe food, increased productivity and profitability and informed decisions on environment management and biosafety policy

Output 4.1: Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented

Summary:
The concept of regionalized crop improvement is being deployed in ESA through funded projects to regionally address common constraints cutting across national borders and also by encouraging sharing of germplasm. To implement the strategy, 5 task networks were involved in addressing constraints on drought through sorghum variety and hybrid evaluation, midge, sweet sorghum as well as on sorghum constraints

expressed in the sub-humid environments and on finger millet evaluation. For finger millet, three entries IESV 92042 SH and IESV 92036 SH and IS 21016 had overall disease damage scores of one, indicating no observed symptoms while variety KNE 392 gave the highest yield. KNE 1149, KNE 689, KNE 688, KNE 1124, Gulu E, KNE 434, P 224, KNE 814, Ending and KNE 1034 had blast scores ≤ 3.0 (on a scale of 1-9).

High yielding pigeon pea genotypes were identified for evaluation in the National Performance Trials (NPT) in Tanzania, Kenya and Malawi. Long duration varieties are highly relevant for traditional maize based cropping systems and high altitude areas. Medium-duration varieties are mostly intercropped, and grown in areas with warm temperatures unsuitable for long-duration varieties. Three students were identified to work on chickpea and pigeonpea breeding. Trained/demonstrated to 9223 and 6163 farmers on pigeonpea and chickpea production technologies, respectively.

Breeder seed of all PVS entries of pigeonpea (medium and long duration varieties) and chickpea (desi and kabuli) was produced for further multiplication with the objective to attain the set target of 10 t seed by 2010. Multiplication of breeder and foundation seed of the released sorghum and finger millet varieties for the ESA target countries was accomplished. The varieties targeted for dissemination in the HOPE project were multiplied at Kiboko in Kenya and Miwaleni research station in Tanzania where ICRISAT was given 20 acres, and established an irrigation system with funds from the GCP project.

Most of the legume work in project 4 is done with the support of a global legume project on "Enhancing grain legumes' productivity and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia" –Tropical Legumes II - which is coordinated and managed from ICRISAT Nairobi. The focus is on germplasm management, enhancement and evaluation for adaptation and resistance to identified key biotic and abiotic stresses. Cereal activities are supported under the HOPE project. To catalyze adoption, a seed system objective is also in place coupled with an objective on situation analyses and outlook, crop improvement and management and marketing. Capacity building is an integral component of both Tropical Legumes II and HOPE, targeting short courses on specific topics for project implementation and post graduate training for future sustainability of project activities.

IPGs:
- Improved cereal and legume germplasm available for evaluation by collaborators
- A platform with clear rules and regulations (SMTA) developed for germplasm exchange among the breeders in the collaborating countries
- A total of 165 farmers and 18 Extension Personnel were trained on improved chickpea production technologies. Six ESA-NARS scientists exposed to about one month training on chickpea breeding and seed production at ICRISAT-Patancheru. Two degree students, one each from Kenya and Ethiopia were registered.

Outcome:
- Collaborators, including farming communities, that participated in short term training (crop management, seed production, field experimentation) are capable to implement project activities better and therefore can produce reliable information on the technologies being developed and evaluated
- Partners attain improved efficiency from use of biotechnology tools; NARS scientists to build/improve their capacity in modern breeding methods.
- Breeding programs have capacity to test and release improved varieties
- Breeders can access new materials from peers and enhance the diversity of the materials in their national programs and therefore increase chances to identify better genotypes
- Farming communities participating in FPVS have upfront information and understanding of the varieties and germplasm they are evaluating with researchers and this will enhance adoption
- Farmers and communities that participated in legume utilization training have increased awareness on nutritious and diversified products and improve potential for adoption.

Impact:
- Adoption of improved cereal and legume varieties in the semi-arid tropics is constrained by the inadequacy of the seed system to reach all farmers in remote area as well as by the lack of product markets to create incentives for farmers' adoption of improved and productivity enhancing technologies. The use of community based seed system and adoption of the Quality Declared Seed grade has been useful in availing seed even to farmers in most remote areas and thus enhance adoptuion of improved varieties to increase productivity. How does this translate into an impact?
- Participatory approaches in verification of varieties, use of alternative seed delivery models and integration of private partners will increase chances for better variety identification, improve seed access for adoption and links to markets will result in improved food security, nutrition and income.

Output target 2009 4.1.1 At least 3 high-yielding medium duration pigeonpea cultivars adapted to southern African cropping systems developed and available with associated capacity development to NARS partners in Tanzania and Malawi

Achievement of Output Target:
100%
Target achieved by supplying medium duration varieties for trials to NARS partners in Tanzania and Malawi. Seed for one medium duration yield trial and one medium duration *Fusarium* wilt resistance screening trial were supplied to Ilonga Agricultural Research station, Tanzania. Seed for two medium duration trials were supplied to three locations in Malawi. Also, one trial for wilt screening was supplied to Malawi.

Participating Countries:
Kenya, Malawi, Tanzania

Participating Partners:
ICRISAT-Nairobi, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe

Progress/Results:
45 medium duration genotypes derived from SD x MD and SD x LD progenies were evaluated at Kiboko and Kampi ya Mawe, Kenya and identified superior genotypes in SD x MD (ICEAPs 00673, 00668/1, 00671/2) and SD x LD (ICEAPs 01179, 01170, 01180/2) possessing

high yield, bold grains and drought tolerance. Pest tolerance screening of 24 genotypes in Kenya showed that ICEAPs 01532, 01549 and 01528 as pest tolerant-cum-high yielding genotypes.

Traditional medium duration varieties are photo and thermo-sensitive, i.e. when they are grown away from the equator (Malawi and parts of Tanzania), their phenology is delayed. Photo and thermo-insensitive varieties developed at ICRISAT-Nairobi were evaluated for high yield potential and adaptation. Among 17 and 46 MD genotypes evaluated in Tanzania and Malawi, ICEAPs 01170, 01169, 01179, 01147, 00665/1, 00673 performed well in Tanzania and 01143/8, 01487/16, 01499/7, 01162/21, 01485/9 in Malawi. Multi-locational evaluation of 7 genotypes at Makoka, Chitala, Bvumbwe and Chitedze in Malawi showed that ICEAPs 01499/7 and 00557 are high yielding genotypes coupled with *Fusarium* wilt resistance.

SN Silim, NVPR Ganga Rao, M Somo, D Ojwang and P Kaloki

Output target 2009 4.1.2 Groundnut variety adaptation trials including on-farm variety tests conducted and monitored in ESA countries

Achievement of Output Target:
100%
Participatory variety adaptation trials and demonstrations using the mother-baby trial concept implemented across the three target countries.

Participating Countries:
Malawi, Mozambique and Tanzania

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, CARE Malawi, Naliendele Agricultural Research Institute Tanzania, Hombolo Research Station Tanzania, Makutopora Research Station Tanzania, Diocese of Central Tanganyika, Diocese of Masasi and Tunduru, KMAS, Dutch Connection, Masasi District Council Tanzania, Dodoma District Council Tanzania, Chamwino District Council Tanzania, Institute of Agricultural Research – Nampula Research Station Mozambique, Inhambane and Nampula Districts Mozambique, ICRISAT Mozambique.

Progress/Results:
A total of 47 Elite Regional Trials and nurseries were distributed to partners and collaborators in 5 countries in ESA (Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). A total of 160 mother-baby trials were planted during the 2008/09 season as follows: Malawi (60), Tanzania (64) and Mozambique (36). The trials covered nine Rural Development Project (RDP) Areas of Malawi. In Mozambique the trials were evaluated in the provinces of Inhambane (12) and Nampula (24) while in Tanzania it was done in a total of 32 villages located in Masasi, Nanyumbu, Mtwara, Bahi and Chamwino districts. All the trials were a repeat of that of the 2007/08 growing season to generate enough information on farmer preferred varieties in all three countries involved. In Nampula province in Mozambique, Mamane (ICGV-SM 90704) was the most preferred Virginia bunch variety followed by ICGV-SM 01731. In the Spanish category, Nametil was the most preferred. Preference in Inhambane province was mainly in the Spanish varieties where Nametil (ICG 12991) and ICGV-SM 99541 came first.

- In Zimbabwe the targeted variety is short season, preferably Spanish bunch with 90 – 110 days maturity. In six different trials where the best available varieties Nyanda and Mwenje were compared side by side with other Elite Spanish varieties, ICGV-SM 99568 was overall 212.5% superior to Nyanda 143.5% superior to Mwenje. Other significantly better varieties were ICGV-SM 99551, ICGV-SM 01510 and ICG 9427. Kernel yields ranged from 1.72 – 2.46 t ha^{-1} compared to 0.77 – 1.16 t ha^{-1} for the controls
- Among the best in Zambia, which could accommodate up to 120 day maturity variety was ICGV-SM 01510, ICGV-SM 99551, ICGV-SM 99530 and ICGV-SM 01514 with kernel yield range of 1.3 t ha^{-1} to 1.6 t ha^{-1} as compared to the released check Luena yield of 0.5 t ha^{-1} – superiority range 260 – 320%
- In Mozambique, the best varieties were ICGV-SM 99541, ICGV-SM 01510, and ICGV-SM 01501 yield range 1.2 – 1.5 t ha^{-1} compared to the check with 0.66 t ha^{-1}
- Tanzania's best was ICGV-SM 01711, ICGV-SM 01721 and ICGV-SM 02724 (1.02 – 1.08 t ha^{-1}) superior to local check Kanyomwa (0.40 t ha^{-1})
- Finally Malawi identified ICGV-SM 05679 from the Advanced short duration, ICGV-SM 06637 from the Elite Aphid & ELS resistance trial, ICGV-SM 01721 from the Regional VB, and ICGV-SM 06690 from the Regional Valencia, all with average kernel yields above 1.5t and over 30% superiority to the standard checks

On-farm trials achieved the following:
- Helped expose over 1438 new farmers to Elite Varieties from Research as follows. Malawi (420), Mozambique (378), and Tanzania (640)
- As a result, the number of entries for on-farm PVS in Malawi were narrowed from 8 to 3 Spanish and two virginia (ICGV-SM 96714, ICGV-SM 99567 and ICGV-SM 01514 Spanish and ICGV-SM 01708 and 01728 Virginia)
- Mozambique from 8 to 3 (ICGV-SM 99568, ICGV-SM 99541, JL 24) all Spanish
- Tanzania identified 5 varieties (ICGV-SM 01721, ICGV-SM 01711, ICGV-SM 99555, ICGV-SM 99557, and ICGV-SM 83708) from this exercise which were all released this year.

ES Monyo, O Mponda, H Charlie, W Munthali and E Sichone-Chilumpha

Output target 2009 4.1.3 At least 3 high-yielding chickpea cultivars adapted to ESA cropping systems tested by NARS in Ethiopia, Kenya and Tanzania

Achievement of Output Target:
100%

Achieved 100% targets, evaluated new desi and kabuli genotypes in Kenya, Tanzania and Ethiopia for drought tolerance, high yield and good grain traits. Both desi and kabuli types are important in ESA chickpea growing countries. Ethiopia released 12 varieties suitable to its agro-climatic situations. Presently, Tanzanian and Kenyan farmers grow only local genotypes that are available to them.

Participating Countries:
Kenya, Tanzania, Ethiopia

Participating Partners:
ICRISAT-Nairobi, Lake Zone Agricultural Research and Development Institute-Tanzania, Kenya Agricultural Research Institute (Njoro) - Kenya, Debre Zeit Agricultural Research Center- Ethiopia

Progress/Results:
17 desi and 17 kabuli genotypes were evaluated in Tanzania and KARI-Njoro and identified superior genotypes in desi (ICCVs 97406, 07304) and kabuli (ICCVs 07112, 07110, 07114) for further evaluation. Through multi-year and -country evaluation selected best genotypes for on-farm evaluation (ICCVs 97126, 97031, 97128, 97125-desi; ICCVs 97306, 00302, 97406, 92311-kabuli).

Evaluated 61 desi and 62 kabuli lines for heat tolerance at Nairobi and supplied best lines of desi (ICCVs 07101, 0712, 07104, 07110, 07114) and Kabuli (ICCVs 07304, 07308, 05312, 07306, 05315) to Kenya and Tanzania.

Evaluated 84-desi and 60-kabuli genotypes at ICRISAT-Nairobi and noted very good genetic diversity for larger seed size among Kabuli. Similarly, a set of 144 genotypes are being evaluated in Ethiopia. Among the Kabuli genotypes tested, descendents of ICCV 92311 x ICC 7344, ICCV 92311 x ICC 11883, ICCV 92311 x ICC 14194, ICCV 95311 x ICC 8155 and ICCV 08313 recorded high seed size (maximum up to 61.7 g) coupled with high yield. In desi nursery, descendents of ICCV 93954 x ICC 4874, ICCV 93954 x ICC 1361, WR 315 x ICC 17109, ICCV 10 x ICC 4874, ICCC 37 x ICC 4552; and ICCV 08108, 08107 and 08110 showed high grain yield coupled with good seed size. Specifically WR 315 x ICC 17109 derived genotypes recorded seed size up to 33.5 g and grain yield of 3.6 t/ha.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, P Kaloki and M Somo

Output target 2010 4.1.1 Three groups of task networks addressing the key constraints of drought and photoperiod response active in sharing improved germplasm regionally

Achievement of Output Target:
100%
There were 5 task networks that were involved in addressing constraints on drought through sorghum variety and hybrid evaluation, midge, sweet sorghum as well as on constraints expressed in the sub-humid environments and on finger millet evaluation
Participating Countries:
Kenya, Tanzania, Zimbabwe

Participating Partners:
NARS partners in Kenya, Tanzania, Zimbabwe

Progress/Results:
Regional Drought tolerant sorghum variety trial
The regional drought tolerant trial consisted of 28 entries (20 selected from the ICRISAT Nairobi advanced drought trial of 2008 and 10 entries from ICRISAT-Bulawayo). Trial sets were tested in Kenya (Kiboko), Tanzania, Zimbabwe, Uganda and Eritrea. Data have been received from Kenya and Tanzania. Planting was delayed as seed from Zimbabwe did not arrive on time. The trial established better at Hombolo (Tanzania) than at Kiboko (poor rainfall) hence better expression was observed at Hombolo than at Kiboko. Twelve lines, IESV 23004 DL, IESV 92043 DL, ICSR 161, Sima, IESV 23007 DL, SP 993442-2, IESV 23008 DL, SP 99350-2, ICSV 93041, IESV 91104 DL, IESV 23011 DL and SP 993515 performed best at both locations with grain yields ranging from 1.017 to 1.694 tha-1. Sima was the best line at Hombolo (2.193 t ha-1) whereas IESV 92046 DL (1.753 t ha-1) was the best at Kiboko. The materials flowered earlier at Kiboko than at Hombolo.

Hybrid Sorghum Evaluation
A total of 377 test cross hybrids were tested for restoration at Kiboko. The nursery suffered from elephant damage in the course of the season and 157 lines were lost. However after evaluation of the remaining lines, 95 lines were fertile. These will be advanced to a preliminary hybrid yield trial.

Sorghum midge
During 2009 LR 25 sorghum lines selected from the advanced and elite midge trials of 2008 were constituted into a Regional midge trial and grown at Alupe. The season had less than normal rainfall and the performance of the lines was average. A total of eight lines (IS 8887, IS 21881, IS 21185, IS 8884, IESV 94114 SH, IESV 94121 SH, IESV 94105 SH, MR 22 x IS 8613/2/3/3/1-2) attained a grain yield of ≥ 1.0 t ha^{-1} and midge damage score ≤ 4.0 (1-9 scale). These lines have also shown stable expression in grain yield and midge tolerance across 3 seasons. The lines are brown/red seeded thus suitable for the humid areas like the lake Victoria zone that are prone to grain molds.

Sub-humid Lake Zone sorghum evaluation
An advanced sorghum trial comprising of 25 elite sorghum varieties targeting Sub-humid lake agro-ecology and a local check were evaluated at Ukiriguru, Tanzania, during the first rains of 2009. Genotype was highly significant for all the traits evaluated (Table 3). Grain yield ranged from 1.61 t ha$^-$ to 0.039 t ha$^-$ with nine of the entries performing better than the local check, Chalagwa (0.94 t ha$^-$). A number of entries showed good resistance to insect and disease damage; with 13 entries having a score of ≥ 2.0 for insect damage and another 13 with $\geq$ 2.0 score for overall disease damage compared with the local check`s score of 2.3 in both. Three of the entries IESV 92042 SH, IESV 92036 SH and IS 21016 had overall disease damage scores of one (no observed symptoms). Entries Wagita, IS8887, IESV 92038/3 SH, IESV 92037 SH and IESV 92030 SH were agronomically better than the local check. Fifteen of the entries formed an advanced trial in the same location the previous year. Wagita was the best yielder in both years while IESV 92030 SH, IESV 92041 SH and IS 8193 were among

the best years during the two years. IS 8887 and Wagita expressed least damage to insects and IESV 92033 SH and IS 25434 least disease damage in the two seasons under study.

Regional Finger millet Trial
The trial was conducted at Kiboko-Kenya in 2008/9 and at Maruku-Tanzania in 2009. At Kiboko, 13 lines had mean grain yields above trial mean (1.52 t ha^{-1}) with yields ranging from 1.556-1.859 t ha^{-1}.   KNE 392 gave the highest yield. KNE 1149, KNE 689, KNE 688, KNE 1124, Gulu E, KNE 434, P 224, KNE 814, Ending and KNE 1034 had blast scores $\leq$ 3.0 (1-9 scale). At Maruku, a similar trend was observed whereby the best performing lines with grain yields ranges of 1.404-2.069 t ha^{-1} were KNE 1149, Acc. 14, KNE 434, KNE 688, KNE 814, Gulu E, P 224, KNE 758 and U 15. Similar results were also observed in Eritrea in 2007. From data obtained in the 3 countries (Kenya, Tanzania and Eritrea)   KNE 1149, KNE 434, and KNE 758 showed a stable performance across the locations an indication of potential for regional release.

Special project funding:
BMZ/GTZ

<div align="right">M Mgonja, H Ojulong, E Manyasa, P Sheunda and J Kibuka</div>

Output target 2010 4.1.3: At least one medium and one long duration pigeonpea variety released in two countries of ESA

Achievement of Output Target:
75 %
Targets by means of identifying high yielding genotypes and processing them for National performance Trials (NPT) in Tanzania, Kenya and Malawi. Long duration varieties are highly relevant for traditional maize based cropping systems and high altitude areas. Medium-duration varieties are mostly intercropped, and grown in areas with warm temperatures unsuitable for long-duration varieties.

Participating Countries:
Kenya, Tanzania, Malawi

Participating Partners:
ICRISAT-Nairobi, Selian Agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe, Kenyan Agricultural Research Institute (Katumani) - Kenya, LELDET Seed Company-Kenya

Progress/Results:
Malawian NARS released one medium duration wilt resistant variety ICEAP 00557 for its cultivation in all three growing regions of Malawi. Also identified 2 long duration (ICEAPs 00576-1, 00932) and 2 medium duration varieties (ICEAPs 01514/15, 01167/11) for potential release in coming years.

In Tanzania, Selian and Ilonga identified ICEAPs 00053, 00932, 00557 and 00554 through FPVS as potential for release and submitted for National Performance Trials by Tanzania Official Seed Certification Institute (TOSCI).

ICRISAT-Nairobi, KARI-Katumani and Leldet Seed Company collaboratively conducted NPT in Kenya involving four medium duration (ICEAPs 00554, 00557, 00850, 00540) and three long duration varieties(ICEAPs 00932, 00933, 00936) at 5 locations. Out of that ICEAPs 00932, 00936 and 00850 were identified for release by KEPHIS.

Special Project Funding:
Nil

<div align="right">SN Silim, NVPR Ganga Rao, P Kaloki and M Somo</div>

Output target 2010 4.1.4: At least 2 MSc students from ESA trained in pigeonpea and chickpea breeding and 2000 farmers trained in their production and management

Achievement of Output Target:
75 %
Targets by identifying 3 students to work on chickpea and pigeonpea breeding. Trained/demonstrated to 9223 and 6163 farmers on pigeonpea and chickpea production technologies, respectively

Participating Countries:
Kenya, Tanzania, Ethiopia,

Participating Partners:
ICRISAT-Nairobi, ICRISAT-Patancheru, Lake Zone Agricultural Research and Development Institute-Tanzania, Debre Zeit Agricultural Research Centre-Ethiopia, Kenya Agricultural Research Institute (Njoro) - Kenya, Selian Agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe

Progress/Results:
One student from Kenya (Peter Kaloki) is working on heat tolerance in chickpea and another student from Ethiopia (Tadesse Safera) is working on molecular characterization of Ethiopian chickpea cultivars. One student from Tanzania (Mayomba Maryanna Maryange) is working on pigeonpea breeding.

In ESA 6163 farmers were trained on various aspects of chickpea production technology, FPVS trials conduction and data collection, improved chickpea varieties, quality seed production, processing and post harvest handing including utilization in Ethiopia(5343), Tanzania(361) and Kenya(459). Similarly 9223 ESA farmers were trained on various pigeonpea technologies through on-farm trials, field days, quality seed production, processing and utilization in Tanzania (7818) and Malawi (1405).

SN Silim and NVPR Ganga Rao

Output target 2010 4.1.5 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and chickpea produced to support on farm trial and demonstrations in 4 ESA countries

Achievement of Output Target:
75 %
Targets, by producing breeder seed of all PVS entries of pigeonpea (medium and long duration varieties) and chickpea (desi and kabuli), to attain the target of 10 t seed by 2010.

Participating Countries:
Kenya, Tanzania, Ethiopia, Malawi

Participating Partners:
ICRISAT-Nairobi, Debre Zeit Agricultural Research Center-Ethiopia, Lake Zone Agricultural Research and Development Institute-Tanzania, Kenya Agricultural Research Institute (Njoro)-Kenya, Selian Agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe

Progress/Results:
ICRISAT-Nairobi produced 3500 kg pigeonpea seed of seven long (ICEAPs 00040, 00053, 00020, 00932, 00933, 00576-1, 00936) and three medium duration varieties (00557, 00554, 00850) for FPVS evaluation and on-farm demonstrations. 2500 kg of breeder seed of nine pigeonpea varieties was produced in Malawi and Tanzania. In Tanzania, 9.58 tons of ICEAP 00053(3.88 t) and ICEAP 00040 (5.7 t) seed distributed to farmers in eight districts for seed multiplication and get back double the quantity of seed for re-distribution. Contract growers in Malawi and Tanzania produced 30 tons of pigeonpea foundation seed of three varieties (ICEAP 00040, ICEAP 00053 and ICP 9145).

2600 kg chickpea seed of five kabuli (ICCVs 97306, 95423, 00305, 96329, 92318) and four desi (ICCVs 97126, 00108, 92944, 97105) varieties was produced at Nairobi. About 1.18 tons of breeder seed of farmer-preferred varieties was produced by NARS partners in Tanzania (1.15 t) and Kenya (0.3 t). In Ethiopia, 24.15 t of breeder seed, 42.65 t of foundation seed and 619.03 t of certified seed of 7 varieties was produced over the past two seasons. 25 tons of foundation seed of ICCV 97105 (8.2t), ICCV00305 (11 t), ICCV 00108 (6.5 t) are expected in Tanzania

SN Silim, NVPR Ganga Rao, M Somo and P Kaloki

Output target 2010 4.1.6 At least 200 kg of breederseed of sorghum and or millet availed to two ESA countries

Achievement of Output Target:
100%

Participating Countries:
Kenya, Uganda, Tanzania, Eritrea, Ethiopia

Participating Partners:
NARS partners, Seed certification agencies, seed companies

Progress/Results:
In preparation for the implementation of the HOPE project objective 6 to: Enable technology adoption of sorghum, pearl millet, and finger millet by improving access to inputs and markets differentiated according to both women and men's needs in WCA, ESA, and SA; we embarked on multiplication of breeder and foundation seed of the released sorghum and finger millet varieties for the ESA target countries. The following varieties were multiplied at Kiboko in Kenya and Miwaleni research station in Tanzania where ICRISAT was given 20 acres and with funds from the GCP project we have established an irrigation system and multiplied the following sorghum and finger millet varieties and corresponding amounts for use in HOPE. ICSV210 (43Kgs), Macia (1104 Kgs), PP290 (36kgs); P9401(35Kgs); Tegemeo 31kgs; KARI Mtama 1(343kgs) and 169 Kgs of the four finger millet varieties P224, Gulu E, Seremi 2, and U15. The total amount is about 359 kgs of breeder seed and foundation seed for 343kgs KARI Mtama and 878kgs of Macia. These seeds will be given to HOPE collaborating partners for further multiplication into foundation and certified seed for delivery to farmers

M Mgonja, H Ojulong, E Manyasa, P Sheunda and J Kibuka

Output 4.2: Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences developed and disseminated with new knowledge to partners

Fusarium wilt is one of the major diseases constraining pigeon pea productivity in ESA. Crosses between parents with large grains and resistance to *Fusarium* wilt have been made and materials are at the F2 generations and selection of resistant plants is continuing. Other crosses were made between parents with high yielding, large grains and pest tolerant attributes and these were between ICEAP 00040 (long duration, wilt tolerant, good grain type) and Mthwajuni; Acc 88 and ICEAP 00576-1(long duration, wilt tolerant, good grain type) to incorporate pest tolerance from Mthwajuni (Malawian germplasm) and Acc 88 (Tanzanian germplasm) to incorporate pest tolerance. An MSc student has been trained in tissue culture regeneration and transformation of locally adapted pigeonpea varieties using the *Agrobacterium tumefaciens* mediated protocol developed at ICRISAT-India. Two short duration (ICPV87039, ICPV86012), one medium duration (ICPV00554) and one long duration (ICPV00040) along with the control variety ICPV88039 were transformed with different

Agrobacterium tumefaciens strains and the GUS reporter gene. Rooting of transformed plants remains a problem and this will be addressed in the next 18 months. A second MSc student in tissue culture regeneration and transformation of locally adapted groundnut varieties using *Agrobacterium tumefaciens* and two transgenic plants of ICGV-90704 were successfully hardened off in the greenhouse.

A majority of chickpea farmers in ESA still growing traditional low yielding wilt susceptible, small seeded genotypes in spite of the availability of superior varieties developed by ICRISAT-Nairobi. Kabuli and desi type varieties have been identified and submitted for NPT targeting release in the near future. The farmers' participatory evaluation of pigeonpea varieties (with direct involvement of farmers in choosing preferred varieties) based on high yield, cream seed color and bold seeds offer a greater scope for varietal dissemination. Participatory evaluation approach is being adopted in Mbere and Makueni districts of Kenya; Babati, Arumeru, Kondoa and Karatu districts of Tanzania; Southern, Central and Northern Malawi.

New issues, demands and opportunities related to health and nutrition are becoming important components of food security, whereas concerns about climate change, energy and environmental safety are in the mainstream of global concerns. On energy, the dual-purpose nature of sweet sorghum, producing both grain and sugar-rich stalk offers new market opportunities for smallholder farmers' integration in production of bio-ethanol as an alternative to fossil fuel. Sweet sorghum cultivars were evaluated in multi environments in Mozambique and Kenya. Varieties IS2331, IESV91104 DL, IESV92008 DL, IS92028 DL, SPV1411, SPV422 and IS93046 have shown consistent performance in terms of traits required for bio-ethanol production and grain yield. It is appropriate to propose the sorghum variety IS2331as a sorghum variety for fast tracking as a feedstock for bioethanol production.

Striga, midge and leaf diseases are among the most serious biotic stresses of sorghum in many parts of SSA. Host plant midge resistance and time of planting are some of the important components for integrated management of the pest. Several sources of resistance to midge have been identified in the previous years and these have been evaluated for midge and leaf disease resistance. Three lines IS8884, IESVs 95005/3-SH and IESV94114SH had low midge, leaf blight and anthracnose scores (1.0 and 3.0) and also had grain yields between 1.2-1.8t /ha. 41 lines with low midge scores ($\leq$3.0), tolerance to leaf diseases and with good yield potential were selected for further testing by NARS targeting Uganda, Tanzania and Southern Sudan where midge and leaf diseases are a threat to sorghum production and productivity

To facilitate dissemination, different categories of seed were produced, starting from small quantities of nuclear and breeder seed for all crop varieties in ESA as well as larger quantities of foundation seed to enhance further multiplication.

IPGs:
- Improved cereal and legume germplasm available for evaluation by collaborators
- A platform with clear rules and regulations (SMTA) developed for germplasm exchange among the breeders in the collaborating countries
- Farmers and Extension Personnel were provided training on crop production technologies on seed production.
- Sorghum lines with 1 to 3 striga resistance QTLs introgressed through MAS ready for evaluation
- Genetic transformation protocols for African varieties of pigeonpea and groundnut available

Outcome:
- Proof of concept that MAB is useful and has practical applications in sorghum production and development
- Private and public sector partners throughout ESA gain access to materials with diversified genetic bases and use these for further selection and evaluation under targeted agro environments
- The activity had the spill-over effects of attracting and securing funds for other related projects and exposing NARS partners to other regional and international partnerships
- Farmers growing ICRISAT mandate crops have experienced increased productivity and enterprise profitability.
- Food quality has been improved due to enhanced nutritional value and reduced aflatoxin contamination in groundnuts
- Increased awareness of the potential benefits and growing acceptance for the use of GMOs throughout the ESA region and policy level discussion on biosafety issues

Impacts:
- Improvement of biotechnology facilities in participating national programs and demonstrated the utility of inter-institutional research collaboration (at both regional and international levels)
- Policy support for biotechnology
- Farmers production and productivity will increase especially if the project links to project 1 on markets policy and institutions

Output target 2009 4.2.1 Three elite farmer varieties of sorghum from three countries carrying 1 to 3 QTLs for *Striga* resistance evaluated through a participatory approach

Achievement of Output Target:
85%
The reason for not achieving the 100% completion was the need to increase the seeds for farmer participatory trials.

Participating Countries:
Sudan, Eritrea and Kenya, Mali

Participating Partners:
NARS partners from the participating countries, University of Hohenheim

Progress/Results:
The activity is 85% achieved - Seeds of 57 *Striga* resistant marker introgression lines comprising four Farmer Preferred Sorghum Varieties (FPVS) from Kenya, Sudan and Mali were increased in two locations in Mali (Sotuba and Samanko) and preparations for on-farm field trials are under way.

In collaboration with the University of Hohenheim, IER (MALI), ARC (Sudan), KARI (Kenya) and NAR (Sudan) significant progress has been made in achieving the milestone. In Eritrea, 22 marker introgression lines carrying 1 and 2 QTLs were evaluated for *Striga* resistance in two sites at Hamamelo and Halhale. Preliminary results show that five lines had resistance comparable to that of N13, the donor parent. In preparation for the farmer participatory trials, seeds of 57 *Striga* resistant marker introgression lines comprising four Farmer Preferred

Sorghum Varieties (FPVS) from Kenya, Sudan and Mali were increased in two locations in Mali (Sotuba and Samanko) and preparations for on-farm field trials are under way. In collaboration with the University of Hohenheim, the 57 *Striga* resistance marker introgression lines were genotyped to confirm homozygosity.

Special project funding:
BMZ/GTZ projects on 1) Introgression of striga resistance into Farmer Preferred sorghum Varieties 2) Individual and combined effects of 5 QTL on resistance to the parasitic weed *Striga hermonthica* in *Sorghum bicolor* under field conditions in Mali and Sudan

<div align="right">D Kiambi</div>

Output target 2009 4.2.2a. At least two NARS availed with sweet sorghum germplasm and accompanying knowledge and tools for evaluation

Achievement of Output Target:
100% achieved as we reached more than 2 NARS

Participating Countries:
Tanzania, Kenya, Namibia, Mozambique

Participating Partners:
Agro Chemical and Food Corporation (ACFC), Sokoine university of Agriculture Tanzania, Kwa Zulu Natal University South Africa, Eco Energia Mozambique

Progress/Results:
Sweet sorghum cultivar evaluations started in 2007. Selections made from all the sweet sorghum variety trials were constituted into an advanced sweet stalk sorghum trial and in addition there were four trials that were constituted evaluated in Kiboko and these included the 1) International Sweet Stalk Sorghum Variety trial (20 entries) 2) Regional Sweet Stalk Sorghum Variety trial (25 entries) 3) International Sweet Stalk Sorghum Hybrids trial (54 entries and 4) the F1 sweet stalk evaluation (64). The NARS partners and specifically the private investors such as the Agro Chemical and Food Corporation (ACFC)-Mohoroni, The Spectre International in Kisumu Kenya; EcoEnergia in Mozambique; The Sokoine University of Agriculture (SUA) MSc and Kwazulu Natal University in South Africa students for their thesis research work and the Tangeni Enterprises in Namibia. The technical support provided included provision of materials for evaluation, on farm visit by our technical staff to Mohoroni to provide field assistance in planting and evaluation of sweet sorghum important parameter, review of thesis proposals and dissertations and assistance in providing ideas for concept note development e.g. with the Tangeni Enterprises. The

Special project funding:
USAID University Linkage Fund for SUA and ICRISAT

<div align="right">M Mgonja, E Manyasa, H Ojulong , P Sheunda and J Kibuka</div>

Output target 2009 4.2.2b. At least two NARS availed with sweet sorghum germplasm and accompanying knowledge and tools for evaluation

Achievement of Output Target:
100%

Participating Countries:
Kenya, Mozambique, Tanzania

Participating Partners:
Agro Chemical and Food Cooperation (ACFC) Mohoroni Kenya, ECO ENERGIA (Mozambique), Sokoine University of Agriculture (SUA) Tanzania

Progress/Results:
Advanced Sweet sorghum trials
Over the past two years, a total of 25 sweet stalk sorghum varieties were evaluated in Kenya (Kiboko-eastern Kenya; Alupe and Muhoroni-western Kenya), Mozambique (Chipemebe, Ocua, Katapua and Namialo), Tanzania and Mauritius. Evaluation at Muhoroni (Kenya) was done in collaboration with Agro Chemical and Food Company (ACFC), a quasi-government institution involved in ethanol production whereas evaluation in Mozambique it was done in collaboration with ECO-ENERGIA, a private company. The varieties were evaluated for Brix (%), stalk juice volume, stalk yields, silage yields and grain yield among other parameters. Results have so far been obtained from Kenya and Mozambique. In Kenya, IS 2331, IESV 92008 DL, IESV 92001 DL, IESV 92028 DL and ICSV 93046, have shown good potential with Brix levels ranging from 11.5 to 15.6% at Alupe, 12.6 to 14.1% at Kiboko and stalk juice volumes ranging from 0.903 to 1.732 KL/ha at Alupe and 2.122 to 5.017 KL/Ha at Kiboko (Table 1). In Mozambique varieties IS 2331, S 35, ICSV 93046, IESV 92008 DL, IESV 92001 DL, and IESV 92021 DL have potential for sweet sorghum production. These varieties had brix levels ranges of 10.5 to 17.6% and stalk juice volumes ranging from 1.38 to 13.31 KL/ha (Table 2).

In Kenya, ACFC has started large scale testing of the potential varieties in target production areas around the factory whereas in Mozambique, ECO-ENERGIA has requested for breeder seed of the 5 varieties identified to start seed multiplication in preparation for large scale testing in target production areas.

For the last two years, ICRISAT has also given technical support to Spectre International –an ethanol producing company in Kisumu, western Kenya. The company relies on sugarcane molasses for its ethanol production but is looking for alternative feedstock in anticipation of the envisaged molasses shortage. The company has already imported and installed a sorghum crushing unit to produce syrup. The syrup will then be fermented and fed into the ethanol production line. In the meantime the company is engaged in seed multiplication of the identified sweet sorghum variety (Ochuti) in readiness for commercial production.

M Mgonja, E Manyasa, H Ojulong, P Sheunda and J Kibuka

Output target 2009 4.2.3 Six newly improved pigeon pea cultivars disseminated through participatory methods in ESA

Achievement of Output Target:
100%
Achieved 100 % targets, identified both medium and long duration varieties suitable for PVS evaluation, conducted PVS in target countries and regions, zeroed on farmer preferred varieties and taken steps to multiply seed of selected genotypes. Majority of pigeonpea farmers in ESA, still growing traditional low yielding, wilt susceptible, photo and thermo-sensitive varieties, in spite of availability of superior pigeonpea varieties developed by ICRISAT-Nairobi. The farmers' participatory evaluation with direct involvement of farmers in choosing preferred varieties based on high yield, cream seed color and bold seeds offer a greater scope for varietal dissemination. Participatory evaluation approach is being adopted in Mbere and Makueni districts of Kenya; Babati, Arumeru, Kondoa and Karatu districts of Tanzania; Southern, Central and Northern Malawi.

Participating Countries:
Kenya, Malawi, Tanzania

Participating Partners:
ICRISAT-Nairobi, Kenya Agricultural Research Institute (Katumani)-Kenya, Selian Agricultural Research Institute-Tanzania, ICRISAT-Lilongwe, Chitedze Agricultural Research Station-Malawi

Progress/Results:
In Makueni and Mbere districts of Kenya, three medium (ICEAPs 00557, 00554, 00850) and two long duration varieties (ICEAPs 00040, 00932) were evaluated under 65 FPVS and 48 demonstrations involving 972 farmers belonging to 25 farmer groups from five divisions. Farmers in general preferred MD over LD varieties.

In Tanzania, 40 FPVS trials were conducted in Babati, Karatu, Kondoa and Arumeru districts with six long duration (ICEAPs 00040, 00053, 00932, 00933, 00936, 00576-1) and two medium duration varieties (ICEAPs 00557, 00554) under TL-II and Treasure legumes. 1284 Farmers participated in FPVS preferred long (ICEAPs 00040, 00053, 00932, 00936) in Babati, Karatu and Kondoa and medium duration (ICEAPs 00554, 00557) varieties in Arumeru.

In Malawi, 35 FPVS trials with participation of 955 farmers preferred ICEAPs 00557 and 00926 in Southern Malawi, and ICEAPs 01514/15, 01162/21, and 001167/11 in Central and Northern Malawi. ICEAP 00557 was released for Malawi and ICEAPs 01514/15 and 01167/11 are being proposed for release in Central and Northern Malawi, based on high yield, cream colored bold seeds, tolerance to drought and *Fusarium* wilt resistance.

SN Silim, NVPR Ganga Rao, M Somo, P Kaloki and D Ojwang

Output target 2009 4.2.3b Four improved chickpea cultivars disseminated through participatory methods in ESA

Achievement of Output Target:
100%
Targets were achieved by organizing PVS trials and demonstrations in Ethiopia, Tanzania and Kenya. A majority of chickpea farmers in ESA, still growing traditional low yielding, wilt susceptible, small seeded genotypes in spite of availability of superior varieties developed by ICRISAT-Nairobi. Participatory evaluation approach is being adopted in Bomet and Nakuru districts of Kenya; Mwanza and Shinyanga, Arusha regions of Tanzania; and in Minjar, Shenkora , Lume/Ejere and Gimbichu districts of Ethiopia.

Participating Countries:
Kenya, Tanzania and Ethiopia

Participating Partners:
ICRISAT-Nairobi, Lake Zone Agricultural Research and Development Institute-Tanzania, Kenya Agricultural Research Institute (Njoro) -Kenya, Debre Zeit Agricultural Research Center- Ethiopia

Progress/Results:
Evaluated two desi (ICCVs 97105, 00108) and four kabuli (ICCVs 00305, 97306, 96329, 92318) varieties in 20 FPVS trials in Tanzania and ICCVs 97105, 00108 and 00305, 92318 as farmer preferred varieties and submitted them for NPT.

In Kenya, four kabuli (ICCVs 96329, 00305, 95423, 97306) and two desi (ICCVs 00108, 97105) were evaluated in 23 PVS sites and identified ICCVs 97105, 00108 (desi) and ICCVs 95423, 00305 (kabuli) as farmers preferred ones and these were identified for release.

In Ethiopia, five kabuli (Ejere, Teji, Shasho, Habru, Arerti) and one desi (Natoli) cultivars were evaluated in 38 FPVS trials. Habru was the most preferred variety followed by Ejere and Arerti.190 demonstrations were planted in the target districts using Habru, Shasho, Chefe and Teji/Ejere.

SN Silim, NVPR Ganga Rao, P Kaloki and M Somo

Output target 2009 4.2.3c Groundnut varieties adapted to ESA evaluated for *Agrobacterium*-mediated transformation response and one scientist trained in the technique

Achievement of Target:
100%

Participating Countries:
Kenya, India

Participating Partners:
ICRISAT, Kenyatta University

Progress/Results:
An MSc student has been trained in the tissue culture regeneration and transformation of locally adapted groundnut varieties using *Agrobacterium tumefaciens*. Three groundnut varieties JL24, ICGV-90704 and ICGV-12991 were subjected to transformation with four different *Agrobacterium tumefaciens* strains (LBA 4404, EHA 105, AGL0 and C58C1, all harboring an identical plasmid) containing the GUS reporter gene and Km resistance (nptII) selectable marker genes.

Plants were regenerated from all three varieties on selection medium containing 50mg/l Km and integration of both the nptII and GUS genes were confirmed in at least 5 plants using PCR. Histochemical staining for GUS activity was not successful. Two transgenic plants of ICGV-90704 were successfully hardened of in the greenhouse to date.

Special Project Funding:
NA

S de Villiers, E Kahariri and J Machuka

Output target 2009 4.2.4. Capacity building through training of local scientists on transformation protocols held at BECA

Achievement of Output Target:
50%
Delays were already experienced in 2008 when work had to be transferred from KARI to the BL2 facility at Kenyatta University for transformation studies. In addition, no appropriate Bt gene constructs could be obtained until a USAID collaboration was initiated in the second half of 2009 which provided access to a soybean codon optimized Bt Cry1Ac gene at the end of November 2009. Therefore regeneration of Bt transgenic pigeonpeas in the lab can only be realized in 2010/2011.

Participating Countries:
Kenya, India, USA

Participating Partners:
ICRISAT, Kenyatta University and University of Nebraska, Lincoln

Progress /Results:
An MSc student has been trained in tissue culture regeneration and transformation of locally adapted pigeonpea varieties using *Agrobacterium tumefaciens*. Four of these varieties, including two short duration (ICPV87039, ICPV86012), one medium duration (ICPV00554) and one long duration (ICPV00040) along with the control variety ICPV88091 were subjected to transformation with four different *Agrobacterium tumefaciens* strains (LBA 4404, EHA 105, AGL0 and C58C1, all harboring an identical plasmid) and the GUS reporter and Km resistance selectable genes.

In this study, ICEAP 00040 germinated poorly and did not produce sufficient leaf explants for transformation while regenerated shoots of ICEAP 00554 did not develop beyond shoot elongation. Therefore, the two short duration varieties, ICPL 87039 and ICPL 86012, were used for transformation and their shoots regenerated on media supplemented with 125mg/l of kanamycin. ICPL 86012 recorded a transformation frequency of 3% each with strains LBA 4404 and EHA 105 and 2% with AGLO. ICPL 87091 achieved a 3% transformation frequency with strain EHA 105 that were confirmed with PCR amplification of the nptII and GUS genes. However, rooting of transformed plants remains a problem. This will be addressed within the next 18 months in the collaboration with the University of Nebraska, along with the need to transform medium and long duration varieties for Africa.

Special Project Funding:
USAID – Linkage Fund: Combating pod borers of pigeonpeas in Africa

S de Villiers, T Changa, J Machuka

Output target 2009 4.2.5 GRAV CP transgenic groundnuts evaluated in a confined greenhouse trial for resistance to Groundnut Rosette Disease

Achievement of Output Target:
100%
The third and final planting of GRAV CP transgenic groundnuts were done in November 2008 at the ARC-Roodeplaat in South Africa and they were infected with GRD-carrying aphids. Although complete infection of all negative control plants were not achieved, there were no GM GRAV-CP lines that showed any clear resistance to rosette disease.

Participating Countries:
Kenya, India, South Africa

Participating Partners:
ICRISAT, ARC-Roodeplaat, South Africa

Progress/Results:
In November 2009, 31 GRAV-CP transgenic groundnut lines as well as 10 non-transgenic controls were planted in a BSL2 greenhouse in South Africa. These were infected with aphids carrying the GRD complex. However, complete infection was not achieved. Despite this fact, none of the GM groundnuts showed any clear resistance to GRD, which confirms the results obtained with the previous two trials.

Special Project Funding:
None

S de Villiers and L van Emmenes

Output target 2009 4.2.5 Groundnut Breeding activities (and associated phenotyping facilities) initiated in at least one research station in Malawi and Tanzania

Achievement of Output Target:
100%

Participating Countries:
Malawi, Tanzania

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Research Station in Tanzania.

Progress/Results:
- A total of 48 new crosses have been initiated at ICRISAT Malawi involving ICG 7878 and 69-101 which are good sources for rust, ELS & LLS resistance from West Africa. These traits are being incorporated into the popular varieties from the region and include: Chalimbana 2005, Johari, Nyota, Red Mwitunde, Pendo, 55-437, Fleur 11, 47-10, ICGV 86124, Chalimbana, CG 7 and JL 24.
- In Tanzania, crosses involving the susceptible popular variety and a rosette resistant source (Pendo x ICGV–SM 90704) were initiated in January 2009. New crosses introgressing pod size, drought resistance and oil content and disease resistance into recommended varieties are planned.
- In order to strengthen hybridization facilities, the following activities have been implemented:
  - Two refrigerators for cold storage of seeds have been purchased for Tanzania.
  - A borehole to source water for irrigation has been completed in Tanzania.
  - Construction of rain out shelters, purchase of materials for greenhouse and construction of working area to keep sensitive equipments is in progress in Tanzania
- In Malawi rain out shelter is under construction, 2 glass houses are being refurbished, 1 portable weather station has been purchased and irrigation pump was purchased for Kasinthula Research Station for drought work.

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

ES Monyo, O Mponda, T Kapewa, H Charlie,
E Sichone-Chilumpha and W Munthali

Output target 2009 4.2.6 Locally adapted pigeonpea varieties evaluated for genetic transformation using Agrobacterium strains marker genes and different promoters and at least one scientist trained

Achievement of Output Target:
85%
Locally adapted pigeonpea varieties could be transformed with marker genes although rooted transgenic plants were not obtained. One MSc student was trained.

Participating Countries:
Kenya

Participating Partners:
ICRISAT, Kenyatta University, University of Nebraska, Lincoln Progress /Results: An MSc student has been trained in tissue culture regeneration and transformation of locally adapted pigeonpea varieties using the Agrobacterium tumefaciens mediated protocol developed at ICRISAT-India. Four of these varieties, including two short duration (ICPL 87039, ICPL 86012), one medium duration (ICEAP 00554) and one long duration (ICEAP 00040) along with the control variety ICPV88091 were subjected to transformation with four different Agrobacterium tumefaciens strains (LBA 4404, EHA 105, AGL0 and C58C1, all harbouring an identical plasmid) and the GUS reporter and Km resistance selectable genes.

In this study, ICEAP 00040 germinated poorly and did not produce sufficient leaf explants for transformation while regenerated shoots of ICEAP 00554 did not develop beyond shoot elongation. Therefore, the two short duration varieties, ICEAP 87039 and ICEAP 86012,, were used for transformation and their shoots regenerated on media supplemented with 125mg/l of kanamycin. ICPL 86012 recorded a transformation frequency of 3% each with strains LBA 4404 and EHA 105 and 2% with AGLO. ICPL 87091 achieved a 3% transformation frequency with strain EHA 105 that were confirmed with PCR amplification of the nptII and GUS genes. However, rooting of transformed plants remains a problem. This will be addressed within the next 18 months in the collaboration with the University of Nebraska, along with the need to transform medium and long duration varieties for Africa.

Special Project Funding:
US-AID Linkage Fund since August 2009

S de Villiers, T Changa and J Machuka

Output target 2009 4.2.7 At least 1 t breeder seed of 3 released farmer/market preferred groundnut varieties in ESA produced annually from 2008 to 2011 as source for foundation seed for collaborating NARS and other partners

Achievement of Output Target:
100%

Participating Countries:
Malawi, Mozambique and Tanzania – for ESA

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele and Nachingwea Research Stations in Tanzania

Progress/Results:
- For Tanzania a total of 3 tones of the popular variety Pendo was produced from Naliendele (1 ha) and Nachingwea (2 ha) research stations.
- For Mozambique a total of 1035 kgs breeder seed was produced as follows: ICGV-SM 01513 (220 kgs), ICGV-SM 01514 (235 kgs), ICGV-SM 99541 (120 kgs), ICGV-SM 99568 (100 kgs), Nematil (300 kgs) and Mamane (60 kgs).
- Huge quantities of breeder seed was multiplied at Chitedze research station in Malawi in support of regional seed systems development as follows: 25.8 tones from 6 varieties namely Nsinjiro (11 t), Kakoma (0.7 t), Chitala (11.1 t), Baka (0.7 t), MGV 5 (0.5 t) and CG 7 (1.8 t).

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

ES Monyo, H Charlie, W Munthali and C Mukhala

Output target 2009 4.2.7 Format for seed company business plan developed with training manual using the Malawi case study

Achievement of Output Target:
100%

Participating Countries:
Kenya

Participating Partners:
Participating partners included the Seed Science Center – Iowa State University, the Agricultural Seed Agency-Tanzania, and Leldet Ltd in Kenya.

Progress/Results:
The tool is specifically developed for (small-scale) seed companies to achieve two goals. The first is to help generate financial projections regarding a specific period to support the creation of a business plan. By entering all the required input data, the tool will generate an income statement and a balance sheet. The second aim is to support decision-making by enabling the user to change one or more parameters of his/her business setup. If the data is entered according to the current situation and then certain parameters – prices, quantities or capital structure – are changed, the model will calculate the outcome in terms of production, profitability, balance sheet, etc.

The model is built using Microsoft's Excel. There are two files of the tool available. The blank one is ready to use with your own data. The completed one is filled with data from a fictitious seed company to give you an example of the workings of the model. The tool is structured around the Seed Value Chain and starts with the growing of seed, proceeds to the processing and storage, and ends with the sale and distribution of the seed. This manual is organized in the same way as the tool, and each of the following chapters represent one section of the tool.

Special Project Funding:
This work was funded through the USAID-funded Program for the Sustainable Commercialization of Seeds in Africa (SCOSA), the Dutch Government through their support in providing an Associate Professional Officer, and the Bill and Melinda Gates Foundation – funded Tropical Legumes II Project.

RB Jones

Output target 2010 4.2.2 Fine mapping of sorghum midge resistance QTL

Achievement of Output Target:
25%
The actual output target has been delayed due to unavailability of resources, however other midge studies continued

Participating Countries:
Kenya

Participating Partners:
KARI Alupe

Progress/Results:
During 2009 LR 25 sorghum lines selected from the advanced and elite midge trials of 2008 were constituted into a regional midge trial and grown at Alupe. The season had less than normal rainfall and the performance of the lines was average. A total of eight lines (IS 8887, IS 21881, IS 21185, IS 8884, IESV 94114 SH, IESV 94121 SH, IESV 94105 SH, MR 22 x IS 8613/2/3/3/1-2) attained a grain yield ≥ 1.0 t ha^{-1} and midge damage score ≤ 4.0 (1-9 scale). These lines have also shown stable expression in grain yield and midge tolerance across 3 seasons. The lines are brown/red seeded thus suitable for the humid areas like the Lake Victoria zone that are prone to grain molds.

Special project funding:
Nil

D Kiambi

Output target 2010 4.2.5 Segregating long duration pigeonpea populations with large grain and resistance to *Fusarium* wilt developed

Achievement of Output Target:
50%

Achieved 50% targets by making crosses between parents with large grains and resistance to *Fusarium* wilt. *Fusarium* wilt is one of the major diseases constraining pigeon pea productivity in ESA. The virulence pattern existing in ESA is entirely different from that of Asia. The germplasm/cultivars from ESA are offering greater resistance to *Fusarium* wilt.

Participating Countries:
Kenya

Participating Partners:
ICRISAT-Nairobi

Progress/Results:
Crosses were made between ICEAPs 00040 (*Fusarium* wilt resistant) and 00048 (large round grains and extra long duration) and F_2 populations were evaluated at Kabete (selected for large grain) and Kiboko (wilt sick location) in 2008/09, to select for large grain and *Fusarium* resistant single plants. 53 individual plants were selected from segregating populations of the cross between ICEAP 00040 (*Fusarium* wilt resistant) and 00048 (large round grains and extra long duration) based on grain yield, maturity duration and 100-seed mass/seed shape, and planted at Kabete to carry out another round of selection for yield components and lateness (at high altitude).

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, M Somo and P Kaloki

Output target 2010 4.2.7 Segregating medium duration pigeonpea populations with large round grains and traits associated with insect pest tolerance developed.

Achievement of Output Target:
50%
Large round grains are preferred in ESA both in terms of superior milling quality and consumer acceptance. Pest tolerance in the field as well as storage conditions provides greater relief to farmers, seed producers and traders with ease in handling. To attain this goal crosses were made between parents with high yielding, large grains and pest tolerant genotypes and achieved 50 % targets.

Participating Countries:
Kenya

Participating Partners:
ICRISAT-Nairobi

Progress/Results: Crosses were made between ICEAP 00040 (long duration, wilt tolerant, good grain type) and Mthwajuni; Acc 88 and ICEAP 00576-1 (long duration, wilt tolerant, good grain type) to incorporate pest tolerance from Mthwajuni (Malawian germplasm) and Acc 88 (Tanzanian germplasm) to incorporate pest tolerance.

152 individual plants were selected from segregating populations of cross between ICEAP 00040 x Mthwajuni to incorporate pest tolerance from Mthwajuni (Malawian germplasm) and planted them at Kabete for further evaluation and selection. The segregating population showed genetic diversity for grain yield, pod hairyness (linked with pest tolerance), 100 seed mass (maximum recorded seed mass up to 26.2 g and 37 plants recorded seed mass >20.0 g), seed colour and seed shape. 37 individual plants were selected from segregating populations of cross between Acc 88 x ICEAP 00576-1 planted them at Kabete for further evaluation and selection.

New crosses were made between medium duration and wilt tolerant genotypes (ICEAPs 00554, 00557) and pest tolerant Mthwajuni (Malawian germplasm) to incorporate pest tolerance in to medium duration genetic back ground as well.

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, P Kaloki and M Somo

Output target 2010 4.2.8 At least 5 kg groundnut nuclear seed of each of 15 varieties in Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA

Achievement of Output Target:
100%

Participating Countries:
Malawi and Tanzania – for ESA

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Agricultural Research Institute Tanzania, Hombolo Research Station Tanzania, Makutopora Research Station Tanzania, Nampula Research Station Mozambique, ICRISAT Mozambique.

Progress/Results:
- In Tanzania a total of 9 varieties were multiplied as follows: ICGV-SM 01711 (44 kg), ICGV-SM 90704 (48 kg), ICGV-SM 99555 (22 kg), ICGV-SM 99557 (5 kg), ICGV-SM 99568 (5 kg), Mnanje (52 kg), ICG 12991 (16 kg), Nyota (29 kg) and Nachingwea (7 kg).
- In Malawi 55 varieties in Elite Regional Trials multiplied with quantities ranging between 5-10 kg for availing to NARS as requested.

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

ES Monyo, H Charlie and W Munthali

Output 4.3: *New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, and marker assisted selection efficiency improved, and specific abiotic stress tolerant varieties and associated knowledge for sorghum, pearl millet and groundnuts developed and disseminated in ESA with associated capacity development*

Summary:
Drought is considered to be the primary cause of yield reductions for crops in sub-Saharan Africa. Intra- and inter-seasonal variations in timing and intensity of rainfall result in drought stresses of various intensities and durations during crop growth. Studies were conducted on the various approaches to address drought and these included developments of early maturing varieties that escape terminal drought, introgression of stay green characteristics indicated by maintenance of green stems and upper leaves when water is limited during grain filling and also crop water management techniques to enhance soil moisture retention.

On crop water productivity, there were no advantages in using either Flat or Tied ridges as a water management system. This may be due to the erratic nature of the rains received that could not allow water to accumulate in the ridges. Through PVS diagnostic and field discussions, earliness to maturity, grain yield and grain color were established as the three most important sorghum selection characteristics by farmers in Chikombedzi. Mahube was identified as a very early maturing variety but was low yielding with low grain numbers per year. Sima was very good after organoleptic tastes with Sila being recommended because of its white grain and high yield.

The marker assisted breeding (genotyping and back-crossing) objectives have been achieved. Two sorghum inbred lines (B35 and E36-1) were used as donor parents for transferring the major stay-green QTL into four farmer preferred local sorghum varieties. Stay-green QTL from B35 and E36-1 were introgressed through marker assisted back-crossing into four farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale). The planned phenotyping of improved lines with introgressed staygreen QTL from India planned for Ethiopia to evaluate the effect of the stay-green QTL in Africa was not achieved due to severe droughts during both cropping seasons in 2009. These will be done in 2010.

To address the problems of GRD, ELS and rust resistance in ESA, recombinant inbred line populations for rosette, ELS and rust were developed and are currently in F3/F4 generations. F1 hybrids have also been developed with an intension of using MABC. Molecular markers for the diseases above in cultivated groundnuts are not yet available. Some progress has been achieved with rust but not rosette or ELS.

IPGs:
- Improved drought tolerant lines available for evaluation by collaborators
- Capacity building and improved skills of collaborators to integrate biotechnology approaches (MAS) with conventional tools for use in breeding for drought
- Stay green products for potential contribution to the crop livestock integration

Outcome:
- Collaborator participating are capable to improve their efficiency from use of biotechnology tools
- Breeders can access new drought tolerant/ stay green materials and therefore increase chances to be able to contribute to the crop livestock and diversification approaches

Impact:
- The potential of the materials under development in this output will benefit from integration of biotechnology and conventional breeding methods
- The products from this output will be beneficial to farming systems that have crop livestock integration
- F2:F3 populations for the foliar disease resistant populations have been produced while more populations incorporating new trait sources have been initiated. Availability of these populations open up room for use of new science tools to speed up progress in crop improvement

IPGs:
- Breeding populations

Impact:
- Fast and efficient breeding programs

Output target 2009 4.3.2 Increased crop water productivity demonstrated with appropriate capacity development for sorghum and pearl millet lines.

Achievement of Output Target:
100%

Participating Countries:
Zimbabwe and South Africa

Participating Partners:
University of Zimbabwe, Chiredzi Research station and Gwebi Research Station

Progress/Results:
Sorghum production in the Limpopo basin of Zimbabwe is constrained by drought, pests and diseases and lack or access to improved varieties with inherent resistance to some of the constraints. Some of the constraints to sorghum production are also due to contemporary plant breeding approaches used by researchers that have led to low adoption rates of improved technologies such as improved varieties. At the Chiredzi Research Station and Gwebi Variety Testing Centre of Zimbabwe a study was initiated to find out if some of the constraints to sorghum production could be addressed using Participatory Variety Selection (PVS). Sixteen sorghum varieties (Subplot factor) were planted in a Split Plot Design, replicated three times using two water management systems (Main plot factor, i.e. Flat and Tied ridges). The station trial was used as a site for the communal trial during the Participatory Variety Selection process with farmers and extension officers from Chikombedzi. The trial was initiated in 2007 by an MSc student at the University of Zimbabwe under my co supervision. Agronomic and Gastronomic data as well as farmer participatory selection data were collected and analyzed using Genstat Version 8. Results showed significant differences (P<0.001) between varieties in agronomic traits (flowering, maturity, plant height, plant lodging and head exertion)

and yield components (number of grains/panicle, mass of 1000 grains and grain yield). There were no advantages in using either Flat or Tied ridges as a water management system. This may be due to the erratic nature of the rains received that could not allow water to accumulate in the ridges. Through PVS diagnostic and field discussions, earliness to maturity, grain yield and grain color were established as the three most important sorghum selection characteristics by farmers in Chikombedzi. Mahube was identified as a very early maturing variety but was low yielding with low grain numbers per ear. Sima was very good after organoleptic tastes with Sila being recommended because of its white grain and high yield.

A similar trial conducted on farm using a number of soil and water management technologies including tied ridges, deep trenches, pot holing and Zai trenches together with well tested participatory approaches (Farmer field schools, mother and baby approach). Varieties were significantly different with Chitichi a local sorghum variety performing better (2.6t/ha) whereas the mean of the improved varieties was about 1.0t/ha. Across varieties, deep trenches were the best water management technologies and there were no significant interaction between water management and varieties. Two improved sorghum varieties (Macia and SV4) as well as two local varieties Chitichi and Sila are the best bet sorghum varieties for the Limpopo basin. The variety Chitichi has a unique capability of ratooning and completing the reproductive cycle with high yields even after a very severe drought. Future breeding activities are including these two local varieties especially in efforts to develop drought tolerant varieties by integrating conventional breeding with MAS. The variety Sila is also being used by a number of brewing companies for producing sorghum based lager beer. On the participatory approaches, trial types (mother vs baby) gave different yields with mother trials performance being better, and this is attributed to the fact that mother trials are better managed than baby trials. This milestone resulted in an MSc thesis and farmer capacity building

Special project funding:
Challenge Program Water for Food Project 1

<div align="right">M Mgonja, T Soko, S Kudita and I Mharapara</div>

Output target 2009 4.3.3: Field evaluations of drought tolerance of stay-green sorghum lines evaluated using a farmer-participatory approach in Kenya

Achievement of output target (originally set for 2008):
95%
The marker assisted breeding (genotyping and back-crossing) objectives have been achieved. The planned phenotyping of improved lines with introgressed staygreen QTL from India planned for Ethiopia to evaluate the effect of the stay-green QTL in Africa was not achieved due to severe droughts during both cropping seasons in 2009. These will be done in 2010.

Participating Countries:
Kenya and Ethiopia

Participating Partners:
ICRISAT – Nairobi, Melkassa Agricultural Research Center

Progress/Results:
Stay-green QTL from two donor parents (B35 and E36-1) were introgressed through marker assisted back-crossing into four farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale). Each generation was analyzed by DNA genotyping at the foreground (to identify individuals with the stay green QTLs introgressed) and background (to identify the individuals with stay-green QTL that had the most recurrent background recovered from the backcrossing) levels to determine which individuals to advance to each subsequent generation. During 2009, BC3F1 of all four varieties were advanced through BC3F3 to fix the introgressed QTLs in the farmer preferred background.

The number of lines advanced across all four recurrent parents to BC_3F_2 was 38 from donor parent B35 and 22 from the donor parent E36-1. Each of these lines contained 1 or 2 target QTLs (of a possible 6 for B35 and 3 for E36-1) and individuals were genotyped to identify those that had the QTLs successfully fixed within the best farmer preferred background. All the possible QTLs were introgressed, either as single introgressions or in combination with one other QTL as a double introgression. The BC_3F_2 progenies will be evaluated for improved drought tolerance conferred by the QTL in the field in Ethiopia alongside introgressed lines from India containing different numbers of Stay-green QTL and that are known to exhibit improved drought tolerance in 2010. An MSc student was trained in DNA extraction, SSR genotyping and data analysis of the BC3F2 population.

Special Project Funding:
Syngenta Foundation for Sustainable Agriculture project: Harnessing modern science in Africa to sustain sorghum and millet production for resource-poor farmers

<div align="right">S de Villiers and G Mugambi</div>

Output target 2009 4.3.4. At least one new breeding population each for GRD, ELS and rust resistance for ESA by 2009

Achievement of Output Target:
100%
Recombinant inbred line populations for rosette, ELS and rust currently in F3/F4 generations
Participating Countries:
Malawi and Tanzania

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Research Station in Tanzania.

Progress/Results:
The initial 56 crosses made between popular but adapted regional varieties with sources of resistance have culminated into contrasting populations as follows:
- 7 GRD F2:3 populations involving the GRV resistant variety ICGV-SM 90704 with such popular varieties as CG 7, Chalimbana, and ICGV-SM 87003; and an Elite GRV resistant source ICGV-SM 94584 with the same varieties plus JL24.

- 6 ELS F2:3 populations involving the two best ELS resistant sources ICGV-SM 95714 and ICGV-SM 93555 with the popular regional varieties Kakoma, Nyanda and Baka,
- 6 Rust F2:3 populations involving the best rust resistant sources ICGV 94114 and ICGV-SM 95342 with the same popular regional varieties Kakoma, Nyanda and Baka

E S Monyo, H Charlie, E Sichone-Chilumpha and W Munthali

Output target 2010 4.3.1 At least 1 backcross population for each farmer preferred variety incorporating one or more sources of disease (GRD, ELS, rust) resistance or drought tolerance for use in marker assisted backcross improvement

Achievement of Output Target:
50%
Molecular markers for the diseases above in cultivated groundnuts are not yet available. Some progress has been achieved with rust but not rosette or ELS.

Participating Countries:
Malawi and Tanzania

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi.

Progress/Results:
- ICRISAT-Malawi successfully produced F1 hybrids between the three farmer-preferred varieties Chalimbana, CG 7 and JL 24 with one source of resistance to GRV ICGV-SM 90704.
- We also produced F1 hybrids between four West African farmer preferred varieties, 55-437, Fleur 11, 47-10 and ICGV 86124 with the above ESA GRV and ELS sources of resistance. These are intended for use in MABC when reliable markers for these traits become available through TL1

ES Monyo, H Charlie, E Sichone-Chilumpha and W Munthali

Output 4.4: Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified transgenic events and non-transgenic germplasm with enhanced micronutrient levels available for evaluation and studies on risk assessment conducted

Summary:
Environmental Risk Assessment is an important pre-requisite for deploying genetically engineered crops.   The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment; leading to loss of biodiversity and destabilization of the ecosystem. The consequence of the transgene movement will however depend on the nature of the transgenic trait. A micronutrient analysis study indicated significant correlations for Fe and Zn (coefficient of 0.547) suggesting that concurrent improvement of Fe & Zn is possible. The hybrid fitness study demonstrated that hybrids between wild and cultivated sorghum could survive under natural conditions but may not necessarily have an advantage over wild sorghum.   Results from another gene flow study suggest that the deployment of GM sorghum in Kenya and Mali will lead to the asymmetrical movement and long-term persistence of transgenes into wild and weedy populations within and around sorghum fields. The rate of gene flow will vary both with sites and variety types, although further work is needed to identify the factors dictating this variability.

Output target 2009 4.4.1 Heritability and correlations among important micronutrient traits determined in sorghum

Achievement of Output Target:
100%

Participating Countries:
Kenya, South Africa, Burkina Faso, Egypt and Nigeria

Participating Partners:
Africa Harvest, CSIR, and University of Pretoria

Progress/Results:
The micronutrient analysis of the 426 sorghum lines from the 5 ABS target countries was conducted and Fe and Zn contents significantly differed between accessions and between countries. Accession IS 18896 from Nigeria had the highest levels of Fe (108.5 ppm) and Zn (44.5 ppm). There were significant correlations for Fe and Zn (coefficient of 0.547) suggesting that concurrent improvement of Fe & Zn is possible. These findings are close to those of Harvest Plus other than that materials evaluated herein expressed higher levels of both Fe and Zn. There was no correlation between Zn/Fe with agronomic traits. A 6X6 diallel crossing program has been initiated to reaffirm the above results on correlation among nutritional traits in sorghum

M Mgonja, H Ojulong, E Manyasa, P Sheunda and J Kibuka

Output target 2009 4.4.2a Knowledge from gene flow studies of non-transgenic sorghum generated and provided with associated capacity development to national regulators.

Achievement of Output Target:
100%

Participating Countries:
Burkina Faso, Kenya and Mali

Participating Partners:
Africa Harvest, Biotechnology Research Network , INERA (Burkina Faso) and ARC (South Africa)

Progress/Results:
The study was conducted to establish hybrid fitness of wild x cultivated sorghum for predicting the destiny of such hybrids in the context of environmental biosafety where transgenes might be included in the wild populations and cause safety concerns.

First (F_1) and second (F_2) generation hybrids developed through artificial hybridization between wild and cultivated sorghum and their parents were evaluated for growth and reproductive traits. Crossing types differed significantly for growth, reproduction-clonal and reproduction-sexual traits. Relative fitness estimates revealed Wild x Cult hybrids to be most fit at growth stage in F_1 and F_2 generations, and for most reproduction-clonal traits in F_2 generation. At reproduction-sexual phase, wild parents were superior to the Wild x Cult hybrids for survival (grain cover) and propagation (shattering, panicle shape and seed size) traits, but were inferior in domestication related traits (panicle and grain weight). Composite relative fitness estimates indicated Wild x Cult hybrids to be most fit, followed by Cult x Wild hybrids in F_1, and wild parents in F_2. The cultivated parents were least fit. However, there were no significant differences in composite fitness across the whole life-history between the hybrids and their wild parents. Results from this study demonstrate that hybrids between wild and cultivated sorghum could survive under natural conditions but may not necessarily have an advantage over wild sorghum. A manuscript developed form this study has been accepted by Crop Science in January 2010.

A transboundary gene flow study has been initiated and this included capacity building of national partners of Kenya, Mali and Burkina Faso

Special project funding:
Africa Biofortified Project funded by the Bill and Melinda Gates Foundation

M Mgonja, H Ojulong, E Manyasa, P Sheunda and J Kibuka

Output target 2009 4.4.2b Knowledge from gene flow studies of non-transgenic sorghum generated and provided with associated capacity development to national regulators

Achievement of output target (originally set for 2008*):*
100%
The project Environmental Risk Assessment of Genetically Engineered Sorghum in Mali and Kenya was successfully completed and the results disseminated in an end-of-project meeting in Nairobi on 29th Sept 2009

Participating Countries:
Kenya, Mali

Participating Partners:
ICRISAT, CIRAD, KARI, IER

Progress/Results:
The results from this project provides new insights on the determinants and effectiveness of sorghum crop-to-wild gene flow in Mali and Kenya. It serves as a methodological case study of a gene flow study between an indigenous crop and its wild relatives in the crop's center of domestication. The conclusions drawn on gene-flow related environmental risks will remain limited due to the impossibility to conduct fitness experiments with GM crops since the Biosafety regulations and legislation does not allow it in sub-Saharan Africa. The substitution with non-GM varieties is not completely satisfactory and the results can therefore not be entirely extrapolated to the case of GM crops.

Overall, the results suggest that the deployment of GM sorghum in Kenya and Mali will lead to the asymmetrical movement and long-term persistence of transgenes into wild and weedy populations within and around sorghum fields. The rate of gene flow will vary both with sites and variety types, although further work is needed to identify the factors dictating this variability. The consequence of the transgene movement will however depend on the nature of the transgenic trait. Further studies are needed to characterize such consequences using crop-wild hybrids. Such hybrids should preferably originate from crosses between wild/weedy sorghum and GM sorghum with various traits considered.

This project trained three PhD and two MSc students and informed key stakeholders and members of the Kenyan Biosafety Committee on the results in an end-of-project meeting in Nairobi in Sept 2009. At least 8 peer-reviewed scientific publications will be produced.

Special Project Funding:
USAID-BBI program

F Sagnard, S de Villiers, M Deu, E Mutegi, M Muraya, L Toure and B Kanyenji

Output target 2009 4.4.3 Farmers' knowledge on wild and weedy sorghum and implications for cultivated sorghum documented with associated capacity development for at least 2 ESA countries

Achievement of Output Target:
90%

The study has been completed in Kenya and because of challenges in getting permits to do the study in South Africa, the project steering committee decided to have the study conducted in another ABS project target country and that is Burkina Faso. The survey was completed in Nov 2009 and report has been drafted and some of the data is still being processed.

Participating Countries:
Kenya, Burkina Faso

Participating Partners:
Pioneer seed, Council for Science and Industrial Research (CSIR-South Africa), Agricultural Research Council (ARC-South Africa), African Agriculture Technology Foundation (AATF), Africa Harvest, KARI-Kenya, and INERA-Burkina Faso]

Progress/Results:
Sorghum (*Sorghum bicolour L*) is one of the most important cereal crops in Africa with wide ranges of races, varieties and feral relatives that are sympatric and sexually compatible. Transgenic technology is among scientific innovations with potential to improve sorghum productivity and nutrition. The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment; leading to loss of biodiversity and destabilization of the ecosystem. A study was conducted in eastern and western Kenya regions between July 2006 and March 2007 using settings intentionally selected to capture variations in culture, agro-climatic and socio-economic conditions. Data was obtained through primary surveys and personal interviews with 881 randomly sampled smallholder sorghum farmers. Descriptive statistics and probit analyses were used on the qualitative and quantitative data respectively, to identify drivers of pollen and seed mediated gene flow.

The study finds that wild/weedy sorghums are widespread in the two regions. More than 91% and 36% of the respondents in western and eastern Kenya respectively are aware of the existence of wild/weedy sorghums. Farmers identify off-types by grain size, maturity stage, shape of the panicle and grain colour. Respondents in western Kenya identified a higher number of sorghum varieties than in eastern Kenya. Agro-ecology of the farms ($p=<0.01$), cultural practices [presence of wild sorghum ($p=< 0.05$) and off types ($p=<0.01$)] and household wealth ($p=0.089$) drive farmers' ability to maintain variety purity. The three factors were negatively related to variety purity maintenance. Farmers maintain variety purity by rouging, removal of off-type panicles after harvest, spatial separation of sorghum fields, selection of seeds prior to planting, and weeding out off-types. The study finds evidence of gene flow in the major sorghum growing areas of Kenya. Agro-ecology, household income and farmers' education and crop handling practices can either promote, or minimize the flow of genes from wild to cultivated sorghum varieties and vice versa. Farmers' environmental and socio economic conditions should be considered as part of the gene flow process, however, the biosafety perspectives ought to focus on the effects and impacts.

In Burkina Faso Sorghum forms a very important part of the cropping system and dietary support in the targeted regions. Overall, 136 cultivated sorghum and 3 wild/weedy sorghum samples were collected from 10 villages in Burkina Faso. Although wild/weedy sorghum was reported to occur in sorghum and other fields in almost all the villages sampled, very few samples were obtained. This is largely attributable to the fact that most farmers are able to identify and manually weed them out before maturity. This finding appears to suggest that wild/weedy sorghum is not an aggressive weed. Interestingly, two of the three samples obtained were collected from fallow fields previously planted with maize (Plate 9 and 10), whereas the other was co-occurring with sorghum in the same

Special Project Funding:
Africa Biofortified Sorghum (ABS)

M Mgonja, E Manyasa, E Mutegi, J Kibuka, H Ojulong and P Sheunda

Output target 2009 4.4.4 Out crossing rates between sorghum and wild species determined

Achievement of Output Target:
100%

Participating Countries:
Kenya

Participating Partners:
ICRISAT, CIRAD, University of Hohenheim, KARI

Progress/Results:
Knowledge of the sorghum mating system is required in order to understand the genetic composition and evolutionary potential of plant populations. Out crossing in a population may co vary with the ecological and historical factors affecting it. However, literature on out crossing rate of wild sorghum is limited in terms of wild sorghum species coverage and eco-geographic reference. Experiments were conducted to investigate the out crossing rates in wild sorghum populations from different ecological conditions. Twelve wild sorghum populations were collected in four distinct sorghum growing regions of Kenya. Twenty four individuals per population were genotyped using six polymorphic simple sequence repeat (SSR) markers to compute their indirect equilibrium estimates of out crossing rate. In addition, the twelve populations were planted in a field in a randomised block design with five replications. Their progeny were genotyped with the six SSR markers to estimate multilocus out crossing rates. Indirect equilibrium estimates of out crossing rates ranged from 7.0% to 75.0%, while multilocus out crossing rates (tm) ranged from 8.9% to 70.0% with a mean of 49.7%. Results indicated that wild sorghum exhibits a mixed mating system. The wide range of estimated out crossing rates in wild sorghum populations indicate that environmental conditions may exist under which fitness is favoured by out crossing and others under which self-pollination is more advantageous.

Special Project Funding:
USAID-BBI project "Environmental Risk Assessment of Genetically Engineered Sorghum in Mali and Kenya".

Fabrice Sagnard, Heiko Parzies and Moses Muraya

Output 4.5: Technological options and knowledge to reduce aflatoxin contamination at different stages of the groundnut crop cycle developed and disseminated to partner NARES, traders and processors in ESA with associated capacity building for enhanced food and feed quality

Summary:
Several mycotoxins contaminate food crops of the poor in the SAT. Among these, aflatoxins, which are toxic, carcinogenic, and immuno-suppressive substances, contaminate groundnut, maize, cotton, chilies, and many other agricultural commodities. Management of contamination of food and food products by mycotoxins has proven to be a difficult challenge in developing countries. This is due to a lack of awareness, stringent food safety regulations and their implementation, environmental conditions and farming practices that are conducive for the contamination. Farmer Field Schools (FFS) are now successfully used in ESA to promote aflatoxin management practices on farmers' fields. Awareness of the problem is also easily discussed and understood using the informal learning nature of FFS. One hundred thirty four FFS in Malawi and 80 FFS in Tanzania are now operational and every season new ones are formed as farmers' enthusiasm for learning picks up. In Malawi, this concept has reached 4020 households whereas in Tanzania we have reached 1200 farm families. Soil samples and groundnut product samples were analyzed and the majority of samples were contaminated with a predominance of *A. flavus*,

Framers, seed producers, extension officers and marketers have been trained on seed production

Output target 2009 4.5.1 Atoxigenic strains of A. flavus isolated from ESA soils

Achievement of Output Target:
100%

Participating Countries:
Kenya, Malawi

Participating Partners:
Participating partners included the University of Georgia, the Kenya Agricultural Research Institute (KARI), and the National Smallholder Farmers' Association of Malawi (NASFAM). This work was funded through a USAID Linkage Grant, and from the USAID-funded Peanut Collaborative Research Support Project (CRSP).

Progress/Results:
162 soil samples were collected during a survey of the major peanut growing areas of Kenya and Malawi. Soil samples were analyzed to characterize the native *Aspergillus* species. Isolates of five species (*A. flavus, A. parasiticus, A tamarii, A. caelatus,* and *A. alliaceus*) within section *Flavi* of the genus *Aspergillus* along with *A. niger* were recovered with varying frequency from both Kenyan and Malawi soils, with *A. flavus* and *A. niger* being the most predominant species. A total of 259 mainly *A flavus* (but also a few *A. parasiticus*) isolates were screened for production of aflatoxins B1, B2, G1, G2 and cyclopiazonic acid. Nine atoxigenic isolates of *A. flavus* were identified as promising candidates for use in biological control of aflatoxin through competitive exclusion. These isolates are currently stored at ICRISAT Nairobi.

1,000 groundnut product samples were collected from traders and processors in western Kenya and Nairobi and analyzed for aflatoxin and *A. flavus, A. parasiticus, A tamarii, A. caelatus,* and *A. alliaceus* within section *Flavi* of the genus *Aspergillus*. The majority of samples were contaminated with a predominance of *A. flavus*, but the analysis is still ongoing. A complimentary marketing survey was also carried out to determine marketing handling practices that have a direct impact on aflatoxin contamination, and these were found to include: poorly-ventilated storage structures, and poor packaging.

Special project funding:
USAID-funded Lucrative Legumes Project in Kenya.

Richard Jones

Output target 2009 4.5.2 Trainers trained in quality on-farm seed production with pre- and post harvest aflatoxin control measures available in at least 2 ESA NARS

Achievement of Output Target:
100%

Participating Countries:
Kenya, Malawi, Tanzania

Participating Partners:
Participating partners included the Kenya Agricultural Research Institute (KARI), and the National Smallholder Farmers' Association of Malawi (NASFAM). ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, CARE Malawi, Naliendele Agricultural Research Institute Tanzania, Diocese of Central Tanganyika, Diocese of Masasi and Tunduru, KMAS, Dutch Connection, Masasi District Council Tanzania, Dodoma District Council Tanzania, Chamwino District Council Tanzania

Progress/Results:
Ten trainers from the National Smallholder Farmers' Association of Malawi (NASFAM), and from five farmer groups in Western Kenya were trained in quality on-farm seed production. Pre- and post-harvest control measures included the use of good agronomic practices - specifically the establishment of adequate plant stands, and drying of pods after lifting. A short documentary film "Harvesting Hope" was made to demonstrate the use of in-field groundnut drying techniques to avoid aflatoxin contamination and to preserve pod quality.

Special Project Funding:
This work was funded through the Irish Aid-funded Malawi Seed Industry Development Project in Malawi, and the USAID-funded Lucrative Legumes Project in Kenya, Bill and Melinda Gates Foundation,

RB Jones, ES Monyo and O Mponda

Output target 2009 4.5.3 Farmer Field School (FFS) concept used with participatory farmer variety selection in adaptive trials to provide input into groundnut breeding and promote aflatoxin control practices in 2 ESA countries from 2009

Achievement of Output Target:
100%

Participating Countries:
Malawi

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, CARE Malawi.

Progress/Results:
The FFS methodology was used in management of aflatoxin contamination. Farmers in Malawi and Tanzania organized into FFS groups were able to validate and promote options for management of Aflatoxin contamination of Groundnut. A mother-baby trial design was used. Mother trials were planted at 4 farmers fields per district with each farmer having all the three treatment combinations. Each mother trial was flanked by two Baby Trials. A total of twenty two (22) farmers were involved in the running of the Aflatoxin trials for the two Districts. Ridges were spaced at 75cm between rows and 10cm between planting stations. Plots contained 4 rows each 20m long. Ridges were boxed every 2m. Groundnut samples were taken to Chitedze Research Station and after drying; a 300g random sample was subjected to aflatoxin analysis using the Enzyme Linked Immuno-Sorbent Assay (ELISA).

Overall results for the treatment combinations show no significant differences in Aflatoxin levels, p =0.05. for this season. Use of box ridges however, had lower aflatoxin levels compared to open ridges, 121 ppb and 129 ppb respectively in the susceptible variety (ICGV-SM 99568) and 3ppb compared to 4ppb for box and open ridges respectively in the resistant variety, J 11. The difference in levels between the two treatments is relatively lower compared to that of 2007/08 season. This is attributed to sufficient rainfall received in the 2008/09 rainy season. Results of the two seasons are however consistent. In the absence of moisture stress, use of box ridges in overall performance did not show much impact (66ppb for open ridges and 62 for box ridges) in terms aflatoxin concentration. For time of planting: late planting had higher levels of aflatoxin as compared to early planting, 85 ppb and 43 ppb respectively. ICGV-SM 99568, a susceptible variety had a higher level of aflatoxin than J11, 125 ppb vs 3.75ppb respectively. These differences provide enough evidence for farmers that planting early and use of resistant varieties is key towards reducing levels of aflatoxin in groundnuts at farm level. Results from on farm trials are also consistent with those conducted on station under irrigation and water stress conditions.
Special Project Funding:
McKnight Foundation

ES Monyo, B Chinyamunyamu, C Nakhumwa,
E Sichone-Chilumpha and W Munthali

Output target 2009 4.5.4 Business plan developed for mycotoxin testing facility with associated training manuals

Achievement of Output Target:
75%
The training manuals have been developed and training programs are yet to be organized. There is need to integrate this proposed activity with other projects to ensure access of funds to organize the training. The training manual may need to be translated into other important and widely spoken languages for better dissemination of the technology.

Participating Countries:
Kenya, Malawi

Participating Partners:
Participating partners included the Kenya Agricultural Research Institute (KARI), and the National Smallholder Farmers' Association of Malawi (NASFAM).

Progress/Results:
Business plans were developed for mycotoxin testing facilities in Malawi and Kenya. These business plans have been used to determine the costs of analyses, and this information is being used for invoicing purposes by both facilities to ensure sustainability of operations. A draft training manual on how to develop the business plan, which is based on Microsoft's excel has been developed but is yet to be published.

Special Project Funding:
This work was funded through the USAID-funded Peanut Collaborative Research Support Program (CRSP), and the Dutch Government through their support in providing an associate Professional Officer.

RB Jones

Output target 2010 4.5.1 Role of variety/genotype contribution to aflatoxin control documented in Sorghum and groundnut in ESA

Achievement of Output Target:
100%

Participating Countries:
Malawi

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi,

Progress/Results:
Twenty-five (25) test lines were planted in pots subjected to the two water treatments (stressed and non-stressed). There were significant differences, $p=0.05$, in the levels of aflatoxin in the test materials. Under water stress, aflatoxin levels were higher ranging from 0.0 to 299 ppb than the irrigated treatment, 0.264 to 31 ppb. J11, a known source of aflatoxin resistance recorded low aflatoxin levels (<5.394ppb) in both treatments consistent with the on-farm findings.

Special Project Funding:
McKnight Foundation

<div align="right">ES Monyo, B Chinyamunyamu, C Nakhumwa,
E Sichone-Chilumpha and W Munthali</div>

Output target 2011 4.5.1 Farmer-friendly literature in vernacular languages (Swahili and Chichewa) on improved groundnut varieties and integrated crop management technologies available to farmers in Malawi and Tanzania.

Achievement of Output Target:
100%

Participating Countries:
Malawi, Tanzania

Participating Partners:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi,

Progress/Results:
A flyer on improved groundnut production practices (2000 copies) was printed in Kiswahili ('Kanuni bora za kilimo cha karanga') and distributed to farmers, students and other stakeholders in Tanzania. A booklet on quality seed production in groundnut ('Jinsi ya kuzalisha mbegu bora za karanga') has been published in Kiswahili (2000 copies) and is available for distribution. Circulars/flyers on variety description were developed and distributed to farmers during agricultural field and open days in Malawi. A flyer on crop husbandry and management of aflatoxin contamination (1000 copies) was printed in Chichewa and distributed during field days to extension staff, farmers and other stakeholders in Malawi.

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

<div align="right">ES Monyo, O Mponda, H Charlie, W Munthali and E Sichone-Chilumpha</div>

MTP Project 5:   **Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (sorghum, pearl millet and pigeonpea) through genetic improvement**

Project Coordinator: **KN Rai**

Highlights for 2009

- Significant progress was made in developing seed parents, restorers and experimental hybrids with high sugar yield in sweet sorghum research, laying a good foundation for the development of commercial sweet sorghum hybrids.
- In pearl millet leaf blast research, effective field and greenhouse screening techniques were standardized and high levels of resistance were found in improved breeding lines and hybrid parents that had not been specifically bred for blast resistances.
- In two sets of pearl millet experiments examining the relationship between molecular marker-based genetic distances and heterosis for grain yield, there were indications of non-significant correlation between genetic diversity of the parental lines and grain yield heterosis.
- Using the introgression lines with stay-green QTL in two diverse genetic backgrounds in sorghum, it was observed that some of the QTLs led to increases in water extraction and transpiration efficiency, but these advantages conferred by the QTL varied depending on the genetic background.
- A preliminary evaluation of 85 commercial and released hybrids of pearl millet showed 13 of these having > 80 ppm grain iron and > 60 ppm grain zinc contents. These results are being re-evaluated in the light of recent research result which showed that reduced seed set can substantially lead to overestimation of grain iron and zinc content.
- A Linex Tester genetical study showed that, in general, hybrids had Fe and Zn contents in between the parental values and that there was highly significant and positive correlation between performance *per se* of the lines and their average hybrid performance (a measure of general combining ability).
- High-yielding maintainer and restorer lines of sorghum with large grain size and good grain luster as farmers preferred grain traits adapted to postrainy season environments were developed for designation, dissemination and use in postrainy season hybrid development.
- Evaluation of shootfly QTL introgression lines along with the two susceptible near-isogenic recurrent parents showed significant effects of these QTL on shootfly resistance (deadhearts %), and its two of the morphological determinants (seedling glossiness score and seedling leaf blade trichome density).
- A genomic region on chromosome SBI-07 with a cluster of putative QTL for resistance to spotted stem borer in sorghum was identified. This QTL cluster accounted for a large (5 - 25%) of the observed variation, and exhibited significant additive affects, for each of the specific resistance-related traits. *In-silico* comparison with maize indicated synteny of this sorghum genomic region with part of maize chromosome 1 previously shown to be associated with stem borer resistance.
- Two open-pollinated varieties of pearl millet developed for forage production were evaluated in a multi-environment trial at Patancheru. Results showed these having high dry forage yield at 80-day harvest, which was comparable to a sorghum –sudan grass hybrid used as a control.
- Several medium-duration hybrids of pigeonpea were identified that had moderate levels of recovery resistance to pod borer damage, with grain yield of >1 t ha^{-1}, which was about twice of the resistant control and five times more than the susceptible control.

Output 5.1: Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite genetic backgrounds made available to defined partners with associated knowledge and capacity building in the Asian SAT

Sorghum

Output target 2009 5.1.1 SO Insect-host genotype-natural enemy interactions and mechanisms of resistance and inheritance clarified (associated with the SP-IPM SWEP)

Achievement of Output Target:
50%
Germplasm and improved lines have been evaluated for multiple insect resistance, studies on resistance mechanisms and genotyping are in progress.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Identify sorghum lines with multiple resistance to insect pests: To identify sorghum lines with multiple resistance to insect pests, and to understand the resistance mechanisms and diversity among the lines that have been identified earlier to be resistant to different insect pests (sorghum shootfly - *Atherigona soccata*, spotted stem borer - *Chilo partellus*, sorghum midge - *Stenodiplosis sorghicola*, and head bugs - *Calocoris angustatus* and *Eurystylus oldi*), over 300 lines were evaluated for resistance to shootfly, stem borer, midge, and head bugs during the 2007/08 postrainy season. The lines showing high levels of resistance to different insect pests or having high to moderate levels of resistance to 2 to 3 insect pests and better agronomic desirability were selected for further testing for resistance to all the four insect species during the 2009 rainy season. The material was divided into three groups; early-, medium-, and long-duration.

One hundred lines belonging to short (<55 days to flowering), medium (55 to 70 days to flowering), and late maturity (70 to 85 days to flowering groups, with resistance to individual or multiple insect species were selected for detailed studies on stability of resistance, resistance mechanisms, and molecular diversity. The test material was planted in 2 row plots, 2 m long, and there were three replications in a randomized complete block design. Data were recorded on leaf glossy score   (1 = glossy, and 9 = non-glossy), shootfly (%), recovery

resistance and overall resistance scores (1= good, and 5 = poor), and agronomic performance (1 = good, and 5 = poor) in the shootfly nursery. For stem borer resistance, the material was screened under artificial infestation, and the data were recorded on leaf feeding (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), deadhearts formation (%), recovery and overall resistance scores (1= good, and 9 = poor), stem tunneling (%), and agronomic desirability (1 = good, and 5 = poor). In the midge nursery, the material was evaluated for midge resistance on a 1 – 9 scale (1= <10 spikelets damaged by midge, and 9 = >80% spikelets damaged by midge). Data were also recorded on plant height and other morphological traits.

During the rainy season in the stem borer screening nursery under artificial infestation, the leaf damage scores ranged from 2.7 to 7.7, and the deadheart formation from 9.2 to 75.6% and 9.2 to 81.7% at 15 and 25 days after artificial infestation in the short-duration lines, indicating very high levels of infestation. The genotypes IS 12308, ICSV 27117, IS 1051, ICSV 117, IS 5480, and IS 4995 suffered <40% compared to 57.6 to 81.1% in TAM 2566. Based on overall resistance scores at maturity (leaf feeding, deadheart formation, and productive tillers), IS 18563, IS 12308, ICSV 93012, ICSV 25027, DJ 6514, ICSV 89057, ICSV 25112, IS 15017, and IS 4995 showed moderate levels of resistance to stem borer.. Of these, IS 18563, ICSV 93012, ICSV 708, DJ 6514, ICSV 89057, ICSV 717, and IS 4995 also exhibited moderate levels of resistance to the sugarcane aphid, *Melanaphis sacchari*. These lines will be useful for developing sorghum cultivars with multiple resistance to insect pests.

During the postrainy season, shootfly infestation remained quite low (1.01 to 34.855 plants with) because of dry conditions, and very high temperatures. However, natural infestation of stem borers, *Chilo partellus* and *Sesamia inferens* was quite high (1.3 to 35.4% plants with at 45 days after seedling emergence). PS 35805, ICSV 25010, ICSV 25026, ICSV 702, ICSV 96031, ICSV 25022, ICSV 93009, ICSV 717, ICSV 711, ICS 93089,and IS 5480 exhibited moderate levels of resistance (<10% plants with) to shootfly and stem borers, and to sugarcane aphid (DR <4.0) among the short-duration lines.

In the medium-duration nursery, the genotypes IS 5490, IS 2122, IS 18368, ICSV 25066, IS 2312, IS 5469 IS 2146, IS 1104, IS 5622, IS 18677, IS 4646, IS 5604, IS 5656, and IS 6566 exhibited moderate levels of resistance to, stem borers, and the sugarcane aphid. In this group, IS 5070, IS 18368, IS 2123, 1S 1044, IS 18579, IS 2146, IS 18551, 1S 1104, IS 5622, IS 25107, IS 1867, IS 14108, IS 466, IS 5604, IS 6566, ICSV 700, and IS 2205 showed resistance to stem borer damage (leaf damage rating <4.0, and <40% plants with compared to leaf feeding damage rating of 6.0 and 82.2% plants with in IS 17610). IS 1044, ICSV 25017, IS 17645, and IS 17610 exhibited moderate levels of resistance to sugarcane aphid, *M. sacchari as well*.

In the rainy season short-duration midge screening nursery, the midge damage scores ranged from 2.3 to 8.3, and 20 genotypes showed high levels of resistance (DR <4.3) to sorghum midge, *S. sorghicola*. Of these, ICSV 705, ICSV 714, ICSV 96011, IS 8891 and ICSV 197 also exhibited resistance to sorghum midge and the sugarcane aphid. In the medium-duration midge screening nursery (45 lines), the midge damage scores ranged from 3.0 to 9.0, IS 19512, IS 7005, and IS 9801 exhibited high levels of resistance (damage rating < 4.0 compared to 8.7 in IS 1054 (Maldandi).

In the postrainy season short-duration midge screening nursery, the midge damage scores ranged from 1.0 to 8.3, and 29 genotypes showed high levels of resistance (DR <3.0) to sorghum midge, *S. sorghicola*. Of these, PS 35805, IS 8151, ICSV 386, ICSV 96011, ICSV 391, ICSV 93009, DJ 6514, IS 15017, and IS 8891 exhibited resistance to both sorghum midge and the sugarcane aphid. In the medium-duration midge screening nursery (45 lines), the midge damage scores ranged from 1.0 to 8.3. IS 19512, IS 9807, IS 7005, IS 3461, and IS 18698 exhibited high levels of resistance to sorghum midge (damage rating 1.0 to 1.3 as compared to 8.3 in IS 1054 (Maldandi).

Physico-chemical mechanisms of resistance to sorghum shootfly, *Atherigona soccata*: We studied the expression of resistance to in relation to morphological traits and biochemical composition of the sorghum seedlings in a diverse array of 15 sorghum genotypes with different levels of resistance/susceptibility to this insect. Susceptibility was associated with high amounts of soluble sugars, fats, leaf surface wetness and seedling vigor; while leaf glossiness, plumule and leaf sheath pigmentation, trichome density, and high tannin, Mg and Zn showed resistance to. Stepwise regression indicated that Mg, Zn, soluble sugars, tannins, fats, leaf glossiness, leaf sheath and plumule pigmentation, and trichome density explained 99.8% of the variation in damage. Path coefficient analysis suggested that direct effects and correlation coefficients of leaf glossiness, plumule pigmentation, trichomes, Mg, and fat content were in the same direction, and these traits can be used to select for resistance to, *A. soccata*.

Output target 2009 5.1.2 SO Dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents developed (associated with the SLP SWEP)

Achievement of output target:
100%
From the evaluation of forage/sweet sorghum hybrids and hybrid parents, promising parents (A/B-lines and R-lines) that give heterotic hybrids have been identified.

Participating Countries:
India

Participating Partners:
Indian NARS (Public and Private sector)

Progress/Results:
Sweet sorghum preliminary B-line trials (SSPBT): A total of 27 B-lines were evaluated for performance under terminal drought stress during the 2008 postrainy season along with the controls ICSB 38 and SSV 84 in RCBD with three replications. Of these, 19 lines with sugar yield ranging from 0.06 t ha^{-1} to 0.47 t ha^{-1} were superior to both the checks, ICSB 38 (0.06 t ha^{-1}) and SSV 84 (0.04 t ha^{-1}). The days to 50% flowering across these 19 lines ranged from 78 to 84 (ICSB 38: 78 days), plant height from 0.9 to 1.4 m (ICSB 38: 1 m) and Brix (% from 9.2 to 14.6 %). The top five sugar -yielding B-lines include SP 93135 (0.4 t ha^{-1}), SP 2781 (0.27 t ha^{-1}), SP 54819-1 (0.26 t ha^{-1}), SP 93037 and SP 93103 (0.2 t ha^{-1} each).

Sweet sorghum advanced B-line trial (SSABT): Thirty-three advanced B-lines selected previously were evaluated along with the controls SSV 84 and CSH 22SS for performance under terminal drought in SSABT during the 2008 postrainy season in RCBD with three replications. Compared to the best performing control (SSV 84: 0.05 t ha^{-1}) for sugar yield SP08 2036-1, SP08 2065-3, SP08 1026-2, SP08 2060-2 and SP08 1035-2 ranging from 0.2 to 0.3 t ha^{-1} were significantly superior. Among these, the grain yield ranged between 0.9 to 2.2 t ha^{-1} (SSV 84: 2.5 t ha^{-1}) and Brix% between 8 to 11.8% (SSV 84: 9.9%).

A total of 27 B-lines selected from the sweet sorghum preliminary B-lines trial and grain-based preliminary B-lines trial during the 2008 rainy season were evaluated in SSABT during the 2009 rainy season along with the controls ICSB 38 and SSV 84. The trial was conducted in RCBD in three replications. Though the B-lines did not outyield the varietal control SSV 84 (2.6 t ha^{-1}) for sugar yield, 26 of the 27 B-lines were numerically superior over the control ICSB 38. Of these 21 B-lines with sugar yield ranging from 0.9 t ha^{-1} to 2.6 t ha^{-1} were significantly superior to ICSB 38 (0.5 t ha^{-1}). The days to 50% flowering among these 21 B-lines ranged from 67 to 83 days (ICSB 38: 68 days), plant height from 1.6 to 2.9 m (ICSB 38: 1.6 m) and Brix% from 16.0 to 20.5% (ICSB 38: 12.9%). The top five high sugar yielding B-lines include SP 93037 (2.6 t ha^{-1}), SP 85040-1-1 (2.3 t ha^{-1}), SP 85026-1-2 (2.2 t ha^{-1}), SP 54801-2 (2.0 t ha^{-1}) and SP 54819-2 (1.9 t ha^{-1}).

Sweet sorghum preliminary varietal trial (SSPVT): A total of 24 varieties selected from the sweet sorghum advanced progenies trial during the 2008 postrainy season were evaluated in SSPVT during the 2009 rainy season along with the controls CSH 22SS and SSV 84. The trial was conducted in RCBD in three replications. The variety SP 16438-1 with a sugar yield of 4.5 t ha^{-1} was significantly superior to the best performing control CSH 22SS (3.6 t ha^{-1}) while the varieties SP 16439-2 (3.8 t ha^{-1}) and SP 16440-3 (3.8 t ha^{-1}) were numerically superior over it. The varietal check SSV 84 had a sugar yield of 3.1 t ha^{-1}. Among the selected varieties, the days to 50% flowering ranged from 64 to 71 days (CSH 22SS: 64 days) while the Brix% from 15.7 to 17.0 (CSH 22SS: 16.8).

Sweet sorghum advanced varietal and restorer lines trial (SSAVRT): A total of 68 varieties/restorer lines selected from the sweet sorghum preliminary varietal and restorer lines trial during the 2008 rainy season were evaluated in SSAVRT during the 2009 rainy season along with the controls CSH 22SS and SSV 84. The trial was conducted in RCBD in three replications. Sixteen lines with a sugar yield ranging from 3.9 to 4.4 t ha^{-1} were comparable to the best performing control SSV 84 (3.98 t ha^{-1}). These varieties flowered in 69 to 89 days (SSV 84: 83 days), had a plant height ranging from 3.7 to 4.2 m (SSV 84: 4.0 m), Brix% ranging from 17.2 to 18.8 (SSV 84: 18.9).

Sweet Sorghum Advanced Hybrid Trial (SSAHT): A total of 42 hybrids selected previously were evaluated in SSAHT during the 2008 postrainy season along with the controls SSV 84, CSH 22SS and CSH25. Compared to the best performing control CSH25 and SSV 84 (0.3 t ha^{-1} each) for sugar yield, five hybrids ICSA675 x SP 4504-3 (0.8 t ha^{-1}), ICSA38 x SP 4511-2 (0.7 t ha^{-1}), ICSA675 x SP 4495 (0.7 t ha^{-1}), ICSA102 x ICSV 93046 (0.7 t ha^{-1}) and ICSA502 x SP 4511-2 (0.7t ha^{-1}) showed significantly higher sugar yields. Among these five hybrids, the grain yield ranging from 1.5 to 4.7 t ha^{-1} (2.2 t ha^{-1}) and Brix% from 9.8 to 15.0.

On-station evaluation of on-farm trial entries: The elite sweet sorghum hybrids and varieties identified from the breeding program are tested under on-farm conditions to find out their adaptation to the region of interest and the acceptability to the growers. The entries under on-farm testing are also evaluated at the research station to find out their relative performance. Under this trial eight sweet sorghum hybrids (ICSA 84 × E 36-1, ICSA 38 × ICSV 700, ICSA 84 × SPV 1411, ICSA 675 × ICSV 700, ICSA 474 × SSV 74, ICSA 475 × NTJ 2, ICSA 702 × SSV 74 and ICSA 475 × SSV 74) and eight sweet sorghum varieties (SP 4511-3, SPV 422, SP 4487-3, SS 2016, SP 4495, SP 4511-2 and ICSV 93046) were evaluated along with the sweet sorghum variety controls SSV 84 and RSSV9, sweet sorghum hybrid control CSH 22SS and grain sorghum hybrid control CSH 25 in RCBD with three replications at four different stages i.e. flowering, dough , physiological maturity and late maturity in postrainy season 2008. Analysis of variance revealed that stage at harvest is highly significant for sugar yield, Brix%, stalk weight (t ha^{-1}), juice volume (kl ha^{-1}), and bagasse (t ha^{-1}). The mean of sugar yield was highest at physiological maturity (0.5 t ha^{-1}), followed by late maturity (0.5), dough stage (0.2) and 50% flowering (0.2). Brix% was highest at late maturity (14.7) while cane weight (16.5 t ha^{-1}) and juice volume (5.2 kl ha^{-1}) were highest at physiological maturity. Compared to the best control RSSV9 (0.5 t ha^{-1}) and the varietal check SSV 84 (0.3 t ha^{-1}) for sugar yield, ICSA731 x ICSV 93046 (1.3 t ha^{-1}), ICSA474 x SSV 74 (0.9 t ha^{-1}) were significantly superior. Among these varieties, SP 4511-2 recorded the highest sugar yield (0.8 t ha^{-1}). Similar trend was noticed at the late maturity stage.

Eight sweet sorghum hybrids and seven sweet sorghum varieties were evaluated along with sweet sorghum variety control SSV 84 and sweet sorghum hybrid control CSH 22SS in a three-replicated RCBD design during the 2009 rainy season at ICRISAT-Patancheru. Based on the best performing control CSH 22SS (2.8 t ha^{-1}) for sugar yield, SP 4487-3 (2.9 t ha^{-1}) was numerically superior and significantly superior compared to the released sweet sorghum variety control SSV 84 (2.4 t ha^{-1}). The variety SPV 422 (2.8 t ha^{-1}) was significantly superior and the hybrids ICSA 84 × E 36-1 (2.6 t ha^{-1}) and ICSA 702 × SSV 74 (2.6 t ha^{-1}) were numerically superior over SSV 84. SP 4487-3 flowered in 88 days, had a plant height of 3.4 m and Brix% of 20.8 while SPV 422 flowered in 91 days, and had a plant height of 2.9 m and Brix% of 21.6.

On-farm evaluation of pre-released hybrids and varieties: During the 2009 rainy season, an on-farm trial was conducted to evaluate 18 entries that include newly developed sweet sorghum hybrids (7) and varieties (5) along with two controls CSH 22 SS (hybrid control) and SSV 84 (varietal control). The trial was planted in a RCBD with three replications in farmers fields (each field 0.2 ha in area) at Ibrahimbad cluster in Medak District, Andhra Pradesh, India. Data were collected on agronomic parameters and sweet stalk traits. Four hybrids and four varieties ranging from 17 to 20 for Brix% were 2 to 20% superior to CSH 22SS (16%). Three varieties – SP 4511-2, SP 4511-3 and ICSV 93046 were on par with SSV 84 for Brix% (19). Another variety SPV 422 had sugar yield (2.47 t ha^{-1}), significantly higher than CSH 22 SS (1.89 t ha^{-1}) and on par with SSV 84 for sugar yield (2.47 t ha^{-1}) and grain yield (2.83 t ha^{-1}).

Evaluation of sweet sorghum varieties for resistance and downy mildew and anthracnose resistance: A total of 35 elite and 22 advanced sweet sorghum hybrids, 33 B-lines and 65 R-lines were evaluated in 2008 postrainy season; and a total of 56 elite and 46 advanced sweet sorghum hybrids, 32 B-lines and 70 R-lines were evaluated in 2009 rainy season for resistance. A total of 136 sweet sorghum advanced hybrids and 119 hybrid seed parents and multi location test entries (25) were evaluated for disease reaction (anthracnose and grain mold) in 2009 rainy season.

For resistance in 2008 postrainy season, compared to control CSH 22SS (22%), eight elite hybrids showed 8 - 63% less deadhearts (ranging from 8 to 20% deadhearts) and seven among them showed 3 to 9% damage due to stem borer deadhearts (CSH 22SS 11%) and they recorded an aphid score 3 to 4 (CSH 22SS: 3). Among the advanced hybrids, 9 hybrids had 7 - 57% less deadhearts (range 11 – 23%) compared to control (CSH 22SS: 27%) and three among them recorded 5 to 10% damage due to stem borer (CSH 22SS: 12%) and an aphid score 3 to 4 (CSH 22SS: 3). Among the B-lines, 16 B-lines showed 5 - 94% less deadhearts (range 1 – 16%) compared to control (296B:

17%) and nine among them recorded 7 to 12% damage due to stem borer (296B: 13%) and five among them had an aphid score of 4 to 5 (296B: 6). Among the R-lines, 56 R-lines had 14 - 89% less deadhearts (range 3 – 27%) compared to control (296B: 31%) and 40 among them had stem borer damage of 2 to 10% (296B: 11%) and 19 among them recorded an aphid score of 3 to 4 (296B: 5).

For resistance in 2009 rainy season, 11 elite hybrids had 11 - 42% less deadhearts (ranging from 54 – 84% deadhearts) compared to control CSH 22SS (94% dead heats) and they recorded an aphid score of 4 to 6 (CSH 22SS: 6). From advanced hybrids group, 12 hybrids had 5 - 14% less deadhearts (range 80 – 89% deadhearts) compared to control CSH 22SS (93% dead heats) and they recorded an aphid score 4 to 6 (CSH 22SS: 6). In the B-lines, 10 B-lines had 5 - 51% less deadhearts (range 43 – 83%) compared to control (ICSB 38: 88%) and they recorded an aphid score of 4 to 5 (ICSB 38: 5). In the R-lines group, 24 R-lines recorded 5 - 52% less deadhearts (range 44 – 88%) compared to control (SSV 84: 93%) and 15 among them had an aphid score of 3 to 4 (SSV 84: 4).

For anthracnose resistance, data on disease severity were recorded on a 1-9 scale (1 = 0 to <1% leaf area covered with hypersensitive lesions with yellow flecks – highly resistant and 9 = 76-100% leaf area covered with coalescing necrotic lesions with acervuli –highly susceptible) on whole plant basis at the soft-dough stage. Grain mold severity was also recorded in these entries at physiological maturity on a 1-9 scale (1= 0 to <1% mold infection – highly resistant and 9= 76-100% molded grains on a panicle- highly susceptible). Of the 136 elite hybrids, 15 hybrids were found resistant (≤3.0 score) and 42 moderately resistant (score >3 to ≤5) to anthracnose compared to susceptible control CSH 112 with 9.0 score. Eleven hybrids among the 12 hybrids found resistant to anthracnose also exhibited moderate resistance to grain mold ranging in severity score from 2.0 to 5.0. Among the 119 elite B-lines, 70 B-lines were resistant to anthracnose (≤3.0 score) and among them 16 B-lines also showed resistance to grain mold ranging in severity score from 4.3 to 5.0. Among the 25 multi location test entries, 6 lines were resistant to anthracnose (≤3.0 score). Among them one variety/R-line –SPV 422 and hybrid ICSA 38 × ICSV 700 showed resistance to grain mold (PGMR scores 2.0 and 5.0). Sweet sorghum was cultivated in large area (>40 hectares) in farmers fields and on-farm productivity was enhanced (stalk yield 25 t ha^{-1}) by growing the sweet sorghum hybrid CSH 22 SS in 2009 rainy season.

Output target 2009 5.1.3 SO More than 25 scientists and technicians trained in sorghum improvement through an international training course

Achievement of output target:
50%
An international training program was conducted on sorghum improvement in 2007. From the presentations of that training course, the book 'Sorghum Improvement in the New Millennium' was developed and published in 2008. This book will be very handy in organizing such training courses in future.

Participating Countries:
India

Participating Partners:
NARS and Private sector

Progress/Results:
An International learning program on "Sorghum hybrid parents and hybrid research and development" was organized from 6th to 17th February, 2007 jointly by ICRISAT-Patancheru and National Research Center for Sorghum, Hyderabad, India. There were 18 participants from both public and private sectors in India, Philippines, and Sudan. On the similar line, an international training program is proposed for 2010.

Output target 2009 5.1.4 SO Two major putative QTL for stem borer resistance identified

Achievement of Output Target:
50%
Mapping population for stem borer resistance has been phenotyped, genotyping and data analysis are in progress.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:
To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population from cross ICSV 745 x PB 15220 was evaluated for stem borer resistance under artificial infestation in the field as a part of a thesis research. It also included resistant (IS 2205) and susceptible checks (ICSV 1), and the parents (PB 15220 and ICSV 745). Data analysis is in progress to identify QTLs associated with resistance to *C. partellus*.

Output target 2009 5.1.5 SO Techniques to screen for resistance to aphids and shoot bug standardized
Achievement of Output Target:
75%
Greenhouse and field screening techniques have been developed, and are being validated.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Techniques to screen for resistance to sugarcane aphid under greenhouse conditions have been standardized (see 2008/09 annual report). Screening for resistance using nethouse screening technique, and leaf disc assay are in progress. Thirty-one sorghum lines comprising of improved breeding lines and germplasm accessions were screened for resistance to sugarcane aphid, *M. sacchari* during the 2009 postrainy season. There were three replications in a RCBD, and observations were recorded at physiological maturity on aphid damage (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged). The aphid damage scores ranged from 1.67 to 5.33, and the genotypes 61510, 61523, 61582, 61592, IS 40615, and IS 40616, exhibited a leaf damage rating of <3.0 compared to 5.33 in the susceptible check, Swarna. The lines 61582, 61588, 61592, IC 40620, and SLR 8 exhibited moderate levels of resistance to the aphid during the rainy season.

Special Project Funding:
Suri Sehgal Foundation Endowment Fund project on multiple resistance to insects in sorghum

Output target 2010/2011 5.1.1 SO At least six high-yielding and large-seeded male-sterile lines with resistance to shootfly and grain mold (3 each) developed

Achievement of output target:
80% Based on the evaluation of recently developed grain sorghum hybrid seed parents (A/B-lines)/progenies for grain mold resistance, 13 B- lines with PGMR from 3 to 4, and 6 B-lines with SFDH 11-40% were identified.

Participating Countries:
India

Participating Partners:
Nil

Progress and Results:
Grain mold hybrids and parents trial: A total of 22 hybrids along with their parents (7 B-lines and 7 R-lines) and two controls (CSH 23, commercial hybrid; and SPV 104, grain mold susceptible control) were screened for grain mold resistance in screening block, and for grain yield and agronomic traits in a breeding block during the 2009 rainy season. Controls CSH 23 and SPV 104 recorded PGMR score 7.3 and 8.6, respectively. All the test hybrids recorded PGMR score from 3 to 6. For grain yield, five hybrids ICSA 29013 x PVK 801 (5.51 t ha^{-1}), ICSA 29010 x PVK 801 (4.66 t ha^{-1}), ICSA 29012 x PVK 801 (4.26 t ha^{-1}), ICSA 29014 x ICSR 196 (4.23 t ha^{-1}), and ICSA 29014 x PVK 801 (3.73 t ha^{-1}) were significantly superior (16 to 72%) to CSH 23 (2.98 t ha^{-1}) in the breeding block. Of the 14 parental lines, ICSV 25263 (score 3.8) and ICSR 106 (score 3.9) were moderately resistant to grain mold.

Grain mold preliminary B-line progenies trial: Forty B-line progenies were screened along with two controls (CSH 16 and ICSB 101) for grain mold resistance in a screening block and for grain yield and agronomic traits in a breeding block during the 2009 rainy season. Controls ICSB 101 and CSH 16 had PGMR scores 5 and 8. All test entries recorded PGMR score 3 to 7. Thirteen B-lines were had PGMR score 3 to 4, significantly less than ICSB 101. For grain yield two B-lines were significantly superior by 15 and 30% with 2.59 t ha^{-1} and 2.93 t ha^{-1} to ICSB 101 (2.09 t ha^{-1}) in the breeding block with PGMR score 5.0 similar to ICSB 101.

Shootfly hybrids and parents trial: A total of 18 hybrids along with their parents (5 B-lines and 6 R-lines) and three controls (CSH 23, commercial hybrid; IS 18551, resistant control and Swarna, susceptible control) were screened in an screening block for resistance, and for grain yield and other agronomic traits in a breeding block during the 2009 rainy season. In the screening block, the resistant controls IS 18551, Swarna and CSH 23 had 40%, 79% and 77% deadhearts (SFDH). All the hybrids tested had SFDH, ranging from 30 to 91% and seven hybrids had significantly lesser deadhearts (by 4 to 56%) than CSH 23 (SFDH% 77). For grain yield, three hybrids ICSA 29002 x S 35 (3.95 t ha^{-1}), ICSA 29002 x PVK 801 (3.56 t ha^{-1}), and ICSA 29004 x S 35 (3.25 t ha^{-1}) were on par to CSH 23 (3.29 t ha^{-1}) in the breeding block. The parents recorded SFDH from 57 to 94%. Three B-lines ICSB 29001, ICSB 29002, and ICSB 29006 showed significantly less SFDH% (up to 17%) and one R-line, SPV 1411 had SFDH% significantly less (14%) than CSH 23.

Shootfly preliminary B-line progenies trial: A trial consisting of sixteen B-line progenies with three controls (ICSB 409, tolerant high yielding B-line; IS 18551, resistant control and Swarna, shootfly susceptible control) was conducted for evaluation of shootfly resistance in a screening block and agronomic traits evaluation in a breeding block during the 2009 rainy season. In the screening block, ICSB 409 had 60% shootfly deadhearts (SFDH), whereas IS 18551 and Swarna had 18% and 59% shootfly deadhearts. Ten B-lines had SFDH ranging from 27 to 52%, significantly less (by 13 to 55%) than ICSB 409 (60% SFDH); and among them eight B-lines were significantly 16 to 107% superior for grain yield (2.02 and 2.63 t ha^{-1}) compared to ICSB 409 (1.53 t ha^{-1}) in the breeding block.

Advanced A$_1$ B-lines trial (A$_1$BT): An A$_1$BT consisting of 13 elite A$_1$ B-lines and two controls (IS 18551, shootfly resistant control and Swarna, shootfly susceptible control) was conducted during the 2009 rainy season for evaluation of shootfly resistance in a screening block. The control Swarna had 53% shootfly deadhearts and six B-lines had 11 to 40% deadhearts, significantly less by 12 to 76% than Swarna.

Advanced A$_2$ B-lines trial (A$_2$BT): An A$_2$BT consisting of 15 elite A$_2$ B-lines and two controls (IS 18551 and Swarna) was conducted during the 2009 rainy season for evaluation of shootfly tolerance in a screening block. The control Swarna had 80% shootfly deadhearts in and seven B-lines showed deadhearts% 41 to 70 significantly less by 3 to 42% than Swarna.

Special Project Funding:
ICRISAT-Private Sector Sorghum Hybrid Parents Research Consortium

Output target 2010 5.1.3 SO Two F_6 RIL populations developed and QTL for traits associated with grain mold resistance identified

Achievement of Output Target:
60%
Two F_6 RIL populations will be developed by 2010 and $F_{2:3}$ populations will be genotyped for identifying Mresistant QTL. This research would continue to transfer the GM resistant QTL in elite hybrid parental lines, subject to availability of resources.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Phenotype three F_3 populations for grain mold reaction: Random F_3 progenies derived from three F_2 populations were re-evaluated during the rainy season 2009 for grain mold reaction along with resistant and susceptible parents in the sorghum grain mold nursery. Three hundred Sixty-seven $F_{2:3}$ lines from the first cross (Bulk Y-P1 × ICSB 377-P1) were screened. The grain mold scores in the susceptible parent (Bulk Y) and the resistant (ICSB 377) parent were 9.0 and 2.0, respectively. Of the 367 lines, 44 were resistant (score 1.1-3.0), 165 moderately resistant (score 3.1-5.0) and the remaining 158 susceptible to grain mold. Grain mold scores in the 403 $F_{2:3}$ lines from the second cross (SP 2417-P3 × IS 41397-3-P6) ranged from 3.1 to 8.2 compared to 8.0 in SP 2417 (susceptible parent) and 3.0 in IS 41397-3 (resistant parent). Two hundred sixty-six lines had ≤5.0 score and the remaining lines were susceptible. Grain mold scores of 401 $F_{2:3}$ lines from the third cross (ICSB 370-2-9-P2 × IS 8219-P1) varied from 2.1 to 7.7 compared to 7.0 in ICSB 370-2-9 (susceptible parent) and 2.0 in IS 8219 (resistant parent). One hundred sixteen lines were categorized as resistant, 155 moderately resistant and 130 susceptible.

For cross 1 (Bulk Y-P1 × ICSB 377-P1), the frequency distribution of F_3 progeny mean values for grain mold rating showed three peaks, suggesting segregation of at least one major gene for resistance to grain mold in this population. For cross 2 (SP 2417-P3 × IS 41397-3-P6), the frequency distribution of F_3 progeny mean values for grain mold showed a single peak with a near-normal distribution, suggesting quantitative inheritance of grain mold resistance in this cross. For cross 3 (ICSB 370-2-9-P2 × IS 8219-P1), the frequency distribution of F_3 progeny mean values for grain mold showed two peaks suggesting the presence of at least one major gene contributing to grain mold resistance in this set of progenies. These results are similar to those obtained in 2008 screen confirming reliable phenotyping for mold reaction. Phenotypic scores of F_3 progenies from two years' screens (2008-09) for grain mold reaction will be used for QTL analysis.

Genotype two populations and identify QTL for grain mold resistance: $F_{2:3}$ populations of SP 2417-P3 × IS 41397-3-P6 are currently being genotyped using 50 SSR markers for mapping genomic regions contributing to grain mold resistance in white grained sorghum. Bulk segregant analysis (BSA) is being performed to identify putative linked markers in the other two [(Bulk Y)-P1 x (ICSB 377)-P1 and (ICSB 370-2-9)-P2 x (IS 8219)-P1] populations. The selected markers will be used to screen all the F_3 progenies of these crosses to identify DNA markers linked to mold resistance.

Advancing three populations from F_4 to F_5: Based on the genetic diversity studies, 3 pairs of resistant and susceptible parental lines (Bulk Y-P1/ICSB 377-P1, SP 2417-P3/IS 41397-3-P6 and ICSB 370-2-9-P2/ IS 8219-P1) with dissimilarity indices of >0.50 were crossed to develop RIL mapping populations for mapping genomic regions contributing to sorghum grain mold resistance. A total of 367 $F_{2:3}$ lines from Bulk Y-P1 × ICSB 377-P1, 403 from SP 2417-P3 × IS 41397-3-P6 and 401 from ICSB 370-2-9-P2 × IS 8219-P1 were advanced to F_5 generation by single-seed descent. These populations are currently being advanced to F_6 to develop RIL segregating for mold reaction.

Output target 2010 5.1.2 SO At least 30 scientists participate in Sorghum Field Day and select more than 300 breeding lines

Achievement of output target:
Sorghum Scientists Field Day will be held in 2010 as per the schedule.

Participating Countries:
Nil

Participating Partners:
NARS (Public and Private sector)

Progress/Results:
Sorghum consortium consultation day: A total of 22 scientists from the private sector from India participated in sorghum consultation meet conducted at ICRISAT- Patancheru in September 2009. Main focus was on research for postrainy season adaptation. Main suggestions were: Diversify the breeding material with germplasm lines from Ethiopia and Yemen, and Muskwari sorghums. While grain luster is important, grain yield productivity should also be given due emphasis in selection.

Seed supplies: A total of 2443 seed samples of hybrid parents/breeding lines were sent to 21 countries. India received 1348 samples followed by Philippines (389 samples) and Mali (328 samples). Of the 1348 seed samples supplied in India, 540 were sent to public sector scientists, 715 to private sector scientists and the remaining 93 samples to farmers and NGOs/collaborators. Seed in bulk quantities (240 kg) of eight high-yielding/released cultivars and one sweet stalk hybrid were given to 60 farmers. Nucleus seed of ICSV 745 (2 kg), CSV 13 (3 kg) and MR 750 (2 kg) supplied to NARS. CSH 22SS (100kg), SSV 84 (100kg), 93046 (40kg), PVK 801(40kg), SPV 1616 (12 kg) were supplied for demonstration plots in Mahabubnagar District in Andhra Pradesh, India.

Trials and nurseries: Twenty sets of sweet stalk trials/nurseries were sent for evaluation in more than 2 locations each in India, Philippines, Mozambique and Mali. A total of 1078 sweet sorghum lines were supplied in 2009 to 17 countries consisting of mainly 100 preliminary progenies and 181 preliminary hybrids to Philippines and Mali. Philippines received a total of 375 samples followed by Mali (313) and India

(221). Seed of sweet sorghum varieties (2) and hybrids (2) was multiplied and sent to Directorate of Sorghum Research (DSR), Hyderabad, India, for testing in the All India Coordinated Sorghum Improvement Project (AICSIP) locations in the 2009 rainy season.

Output target 2011 5.1.1 SO At least four large- seeded postrainy season-adapted male-sterile lines developed

Achievement of output target:
100%
From the evaluation of postrainy season hybrids and hybrid parents, promising parents (12 R-lines) that give heterotic hybrids have been identified. The information on A/B-lines is presented in 5 A.1.1.1

Participating Countries:
India

Participating Partners:
Nil

Progress/Results:
Postrainy advanced hybrid trial (PRAHT): Fifteen promising postrainy season adapted hybrids selected from preliminary hybrid trial conducted during 2007-08 postrainy season were evaluated in a three replicated RCBD during the 2008 postrainy season along with the controls, M 35-1, SPV 1411 and SPH 840. The hybrid, ICSA 563 × ICSR 161 was the highest grain yielder with 5.5% superiority over the best performing control, M 35-1 (4.43 t ha^{-1}). However 11 hybrids with grain yield ranging from 3.19 to 4.43 t ha^{-1} were comparable to it. Among the 11 hybrids, grain size (g 100^{-1} grains) ranged from 3.37 to 4.07 (M 35-1: 3.79, SPV 1411: 3.81), grain luster score (taken on a 1 to 3 scale, where 1= most lustrous and 3= least lustrous) ranged from 2.0 to 3.0 (M 35-1: 2.0, SPV 1411: 2.3), days to flowering ranged from 69 to 73 days (M 35-1: 75 days, SPV 1411: 78 days), and plant height ranged from 1.6 to 2.6 m (M 35-1: 2.6 m, SPV 1411: 2.5 m).

Postrainy advanced varietal trial (PRAVT): A total of 14 postrainy season adapted varieties selected from postrainy adapted preliminary varietal trial during 2007-08 postrainy season were evaluated in PRAVT during the 2008 postrainy season in a three-replicated RCBD along with the controls M 35-1 and SPV 1411. Eight varieties with grain yield ranging from 3.46 to 4.05 t ha^{-1} were comparable to the best performing control M 35-1 (4.5 t ha^{-1}). Among these, three varieties had better grain luster (score: 1) than M 35-1 and SPV 1411 (score: 1.3), while for grain size seven of them (3.61 to 4.10 g 100^{-1} grains) were comparable to M 35-1 (4.02 g 100^{-1} grains). They flowered in 75 to 79 days (M 35-1: 75 days, SPV 1411: 76 days) and had a plant height of 2.4 to 2.9 m (M 35-1: 2.6 m, SPV 1411: 2.5 m).

Postrainy elite R-lines trial (PREVRT): Eight postrainy season adapted restorer lines selected from advanced R-lines trial conducted during 2007-08 postrainy season were evaluated during the 2008 postrainy season in a three-replicated RCBD along with the controls M 35-1 and SPV 1411. Four varieties with grain yield ranging from 4.2 to 4.6 t ha^{-1} were numerically superior to the best performing control M 35-1 (3.9 t ha^{-1}) by 8 to 18%. They were similar to M 35-1 for grain luster (score: 2) and had a grain size of 3.4 to 3.8 g 100^{-1} grains (M 35-1: 4.3 g 100^{-1} grains). They flowered in 75 to 79 days (M 35-1: 75 days) and had a plant height of 2.5 to 3.1 m (M 35-1: 2.6 m).

Postrainy preliminary R-lines trial (PRPRT): A total of 81 postrainy season adapted restorer lines selected from the F$_7$ progenies during 2007 postrainy season were evaluated in a RPRT during the 2008 postrainy season. The trial was conducted in a RCBD with 3 replications along with the controls NTJ 2 and RS 29. Fifteen R-lines with grain yield ranging from 4.23 to 4.98 t ha^{-1} were comparable to the best performing control RS 29 (5.24 t ha^{-1}). The grain size (g 100^{-1} grains) among the lines varied from 2.07 to 3.21 (RS 29: 1.94 and NTJ 2: 2.78). These lines flowered in 71 to 85 days (RS 29: 87 days, NTJ 2: 75 days) and had a plant height of 1.3 to 2.2 m (RS 29: 1.8 m, NTJ 2: 2.2 m). Two lines had a grain luster score of 2 (RS 29 and NTJ 2: 3).

Output target 2011 5.1.2 SO Relationship between grain and stover yield heterosis and genetic diversity of parental lines assessed

Achievement of output target:
75%
A total of 364 test hybrids were developed from diverse parents based on the genetic dissimilarities observed from genotyping with 30 SSR markers and were evaluated in replicated yield trials for two rainy seasons. Data analysis is in progress.

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
Based on the clustering of 188 sorghum hybrid parents (94 B and 94 R lines adapted to rainy and postrainy seasons) using the SSR marker data, 364 hybrids (64 early maturity group, 176 medium maturity group and 124 late maturity group) were developed using selected B- lines based on the phenology (11 early, 19 medium and 12 late flowering) and selected R-lines (8 early, 14 medium and 14 late flowering). All these hybrids along with parents (80) were evaluated for grain and stover yields and other agronomic traits along with promising hybrids CSH 16 and CSH 23 as control in a triplicate trial in the 2008 postrainy season. The hybrids and parents were randomized together as one experiment.

The objective of this experiment was to find out the correlation between the grain and stover yield heterosis with molecular diversity. We have got one season data and the correlation study of heterosis with morphological diversity is in progress. Some promising hybrids have been identified for grain and stover yields in different maturity backgrounds.

In the early-maturity group, two hybrids were significantly superior to CSH 23 (2.88 t ha^{-1}) by 11 and 13% with grain yield ranging from 3.53 t ha^{-1} to 3.59 t ha^{-1}, and one of these hybrids - ICSA 91002 x ICSR 59 - was significantly superior by 19% for dry fodder yield (10.0 t ha^{-1}) compared to CSH 23 (7.2 t ha^{-1}).

In the medium-maturity group, 70 hybrids were significantly superior to CSH 23 (2.62 t ha^{-1}) by up to 63% for grain yield ranging from 3.18 t ha^{-1} to 4.87 t ha^{-1}. For dry fodder yield, among these 70 hybrids, 34 hybrids were significantly superior to CSH 23 (7.2 t ha^{-1}) up to 52% (range 8.8 t ha^{-1} to 12.8 t ha^{-1}).

In the late-maturity group, 38 hybrids were significantly superior to CSH 23 (2.86 t ha^{-1}) by up to 53% with grain yield ranging from 3.37 t ha^{-1} to 4.88 t ha^{-1} Among these 38 hybrids, 18 hybrids were also significantly superior to CSH 23 (9.2 t ha^{-1}) for dry fodder yield ranging from 11.20 t ha^{-1} to 16.00 t ha^{-1}.

To validate the results in 2009 rainy season, a total of 60 hybrids (20 early maturity group, 30 medium maturity group and 10 late maturity group) developed using B- lines (11 early, 19 medium and 12 late maturity group) and R-lines (8 early, 14 medium and 14 late maturity group) were evaluated in a triplicate trial along with parents (80) for grain and stover yields. In the early-maturity group, all hybrids were significantly superior to CSH 23 (1.07 t ha^{-1}) by 26 to 303% with grain yield ranging from 1.63 t ha^{-1} to 5.20 t ha^{-1}; and one of these hybrids - ICSA 466 x ICSR 25 - was significantly superior to CSH 23 (13.27 t ha^{-1}) by 9% for dry fodder yield (15.23 t ha^{-1}).

In the medium-maturity group, 29 hybrids were significantly superior to CSH 23 (1.22 t ha^{-1}) by 56 to 211% with grain yield ranging from 2.32 t ha^{-1} to 4.63 t ha^{-1} and two of these hybrids - ICSA 90 x ICSR 136 (15.45 t ha^{-1}) and ICSA 89002 x ICSR 147 (17.87 t ha^{-1}) - were significantly superior to CSH 23 (13.67 t ha^{-1}) by 4 and 20% for dry fodder yield.

In the late-maturity group, two hybrids ICSA 271 x ICSR 89062 (2.40 t ha^{-1}) and ICSA 88004 x ICSR 84 (2.67 t ha^{-1}) were significantly superior to CSH 23(1.62 t ha^{-1}) by 35 and 50% for grain yield, and the hybrid - ICSA 271 x ICSR 89062 (18.28 t ha^{-1}) was also significantly superior to CSH 23 (14.63 t ha^{-1}) by16% for dry fodder yield.

These results have implications for cultivar testing and commercialization by NARS. All the hybrids used in experimentation were developed based on the genetic dissimilarities of sorghum hybrid parents observed upon genotyping with 30 SSR markers. Data analysis of grain yield and fodder yield heterosis association with the molecular diversity is underway.

A "preliminary" DArT marker data set received from the service provider (DArT P\L, Australia). Field trials have been completed for two rainy seasons and one postrainy season. A second postrainy season evaluation is currently underway. Upon completion of the 2009-10 postrainy season testcross trials, it will be necessary to perform an across-year within season and across-season across-years analysis to identify separate genotype x environment effects from genotype effects on hybrid performance. We also need to obtain from DArT P\L their approved version of the DArT marker data set, and perform diversity analysis of the sorghum B- and R-line sets (individually and together) based on this DArT marker data set, and based on the merged DArT and SSR marker data sets. Finally, we will need to analyze and interpret the combined phenotypic and genotypic data sets to determine the degree to which yield heterosis can be predicted based on molecular genetic diversity detected by DArT and/or SSR markers.

Genotyping of additional 45 B-lines and R-lines using 20 new SS markers is in progress in addition to the already available 30 SSR markers.

Output target 2011 5.1.3 SO Two putative QTLs for traits associated with grain mold resistance identified from two mapping populations

No report provided

Output target 2012 5.1.1 SO Genotypes with multiple resistance, and diverse mechanisms of resistance to insects identified

Achievement of Output Target:
50%
Germplasm and improved lines have been evaluated for multiple insect resistance, studies on resistance mechanisms and genotyping are in progress.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Identify sorghum lines with multiple resistance to insect pests. To identify sorghum lines with multiple resistance to insect pests, and to understand the resistance mechanisms and diversity among the lines that have been identified earlier to be resistant to different insect pests (sorghum shootfly - *Atherigona soccata*, spotted stem borer - *Chilo partellus*, sorghum midge - *Stenodiplosis sorghicola*, and head bugs - *Calocoris angustatus* and *Eurystylus oldi*), over 300 lines were evaluated for resistance to shootfly, stem borer, midge, and head bugs during the 2007/08 postrainy season. The lines showing high levels of resistance to different insect pests or having high to moderate levels of resistance to 2 to 3 insect pests and better agronomic desirability were selected for further testing for resistance to all the four insect species during the 2009 rainy season. The material was divided into three groups; early-, medium-, and long-duration.

One hundred lines belonging to short (<55 days to flowering), medium (55 to 70 days to flowering), and late maturity (70 to 85 days to flowering) groups, with resistance to individual or multiple insect species were selected for detailed studies on stability of resistance,

resistance mechanisms, and molecular diversity. The test material was planted in 2 row plots, 2 m long, and there were three replications in a randomized complete block design. Data were recorded on leaf glossy score (1 = glossy, and 9 = non-glossy), shootfly (%), recovery resistance and overall resistance scores (1= good, and 5 = poor), and agronomic performance (1 = good, and 5 = poor) in the shootfly nursery. For stem borer resistance, the material was screened under artificial infestation, and the data were recorded on leaf feeding (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), deadheart formation (%), recovery and overall resistance scores (1= good, and 9 = poor), stem tunneling (%), and agronomic desirability (1 = good, and 5 = poor). In the midge nursery, the material was evaluated for midge resistance on a 1 – 9 scale (1= <10 spikelets damaged by midge, and 9 = >80% spikelets damaged by midge). Data were also recorded on plant height and other morphological traits.

During the rainy season in the stem borer screening nursery under artificial infestation, the leaf damage scores ranged from 2.7 to 7.7, and the deadheart formation from 9.2 to 75.6% and 9.2 to 81.7% at 15 and 25 days after artificial infestation in the short-duration lines, indicating very high levels of infestation. The genotypes IS 12308, ICSV 27117, IS 1051, ICSV 117, IS 5480, and IS 4995 suffered <40% compared to 57.6 to 81.1% in TAM 2566. Based on overall resistance scores at maturity (leaf feeding, deadheart formation, and productive tillers), IS 18563, IS 12308, ICSV 93012, ICSV 25027, DJ 6514, ICSV 89057, ICSV 25112, IS 15017, and IS 4995 showed moderate levels of resistance to stem borer.. Of these, IS 18563, ICSV 93012, ICSV 708, DJ 6514, ICSV 89057, ICSV 717, and IS 4995 also exhibited moderate levels of resistance to the sugarcane aphid, *Melanaphis sacchari*. These lines will be useful for developing sorghum cultivars with multiple resistance to insect pests.

During the postrainy season, shootfly infestation remained quite low (1.01 to 34.855 plants with) because of dry conditions, and very high temperatures. However, natural infestation of stem borers, *Chilo partellus* and *Sesamia inferens* was quite high (1.3 to 35.4% plants with at 45 days after seedling emergence). PS 35805, ICSV 25010, ICSV 25026, ICSV 702, ICSV 96031, ICSV 25022, ICSV 93009, ICSV 717, ICSV 711, ICS 93089,and IS 5480 exhibited moderate levels of resistance (<10% plants with) to shootfly and stem borers, and to sugarcane aphid (DR <4.0) among the short-duration lines.

In the medium-duration nursery, the genotypes IS 5490, IS 2122, IS 18368, ICSV 25066, IS 2312, IS 5469 IS 2146, IS 1104, IS 5622, IS 18677, IS 4646, IS 5604, IS 5656, and IS 6566 exhibited moderate levels of resistance to shootfly, stem borers, and the sugarcane aphid.

Among the medium-duration lines, IS 5070, IS 18368, IS 2123, 1S 1044, IS 18579, IS 2146, IS 18551, 1S 1104, IS 5622, IS 25107, IS 1867, IS 14108, IS 466, IS 5604, IS 6566, ICSV 700, and IS 2205 showed resistance to stem borer damage (leaf damage rating <4.0, and <40% plants with compared to leaf feeding damage rating of 6.0 and 82.2% plants with in IS 17610). IS 1044, ICSV 25017, IS 17645, and IS 17610 exhibited moderate levels of resistance to sugarcane aphid, *M. sacchari as well*.

In the rainy season short-duration midge screening nursery, the midge damage scores ranged from 2.3 to 8.3, and 20 genotypes showed high levels of resistance (DR <4.3) to sorghum midge, *S. sorghicola*. Of these, ICSV 705, ICSV 714, ICSV 96011, IS 8891 and ICSV 197 also exhibited resistance to sorghum midge and the sugarcane aphid. In the medium-duration midge screening nursery (45 lines), the midge damage scores ranged from 3.0 to 9.0, IS 19512, IS 7005, and IS 9801 exhibited high levels of resistance (damage rating < 4.0 compared to 8.7 in IS 1054 (Maldandi).

In the postrainy season short-duration midge screening nursery, the midge damage scores ranged from 1.0 to 8.3, and 29 genotypes showed high levels of resistance (DR <3.0) to sorghum midge. Of these, PS 35805, IS 8151, ICSV 386, ICSV 96011, ICSV 391, ICSV 93009, DJ 6514, IS 15017, and IS 8891 exhibited resistance to both sorghum midge and the sugarcane aphid. In the medium-duration midge screening nursery (45 lines), the midge damage scores ranged from 1.0 to 8.3. IS 19512, IS 9807, IS 7005, IS 3461, and IS 18698 exhibited high levels of resistance to sorghum midge (damage rating 1.0 to 1.3 as compared to 8.3 in IS 1054 (Maldandi).

Physico-chemical mechanisms of resistance to sorghum shootfly, Atherigona soccata: We studied the expression of resistance to shootfly in relation to morphological traits and biochemical composition of the sorghum seedlings in a diverse array of 15 sorghum genotypes with different levels of resistance/susceptibility to this insect. Susceptibility was associated with high amounts of soluble sugars, fats, leaf surface wetness and seedling vigor; while leaf glossiness, plumule and leaf sheath pigmentation, trichome density, and high tannin, Mg and Zn showed resistance to shootfly. Stepwise regression indicated that Mg, Zn, soluble sugars, tannins, fats, leaf glossiness, leaf sheath and plumule pigmentation, and trichome density explained 99.8% of the variation in shootfly damage. Path coefficient analysis suggested that direct effects and correlation coefficients of leaf glossiness, plumule pigmentation, trichomes, Mg, and fat content were in the same direction, and these traits can be used to select for resistance to shootfly.

Special Project Funding:
Suri Sehgal Foundation Endowment Fund project on multiple resistance to insects in sorghum

Pearl Millet

Output target 2009 5.1.1 PM Two improved populations of pearl millet with high forage yield potential developed

Achievement of Output Target:
100%
Based on the 6 environments (year x season) trial at Patancheru, two populations ICMV 05555 and ICMV 05777 have been identified that gave dry forage yield of about 10.0-11.0 tons ha^{-1} which were comparable to a Sorghum-Sudan Grass hybrid SSG 59-3 (11.1 t ha^{-1}) used as a control.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Nine newly constituted populations/varieties were evaluated in a trial along with 6 controls in the rainy season of 2005. In this trial, dry forage yield varied from 8.4-17.1 tons ha^{-1} and the best control SSG 59-3 yielded dry forage of 11.7 tons ha^{-1} at 80 days of sowing. ICMV

05555 had the highest dry forage yield of 17.1 tons ha^{-1} followed by ICMV05777 (14.5 tons/ha^{-1}) and ICMV 05222 (12.8 tons/ha^{-1}). The same set of 9 varieties was again evaluated in rainy season of 2006. In this trial the dry forage yield varied from 5.5 to 12.6 ton ha^{-1} and ICMV 05555 gave highest dry forage of 12.6 tons ha^{-1} followed by ICMV 05777 (11.8 tons ha^{-1}) and ICMV 05222 (11 tons ha^{-1}) against SSG-59-3 (9.5 tons ha^{-1}). These selected three varieties (ICMV 05222, -05555 and ICMV 05777) were re-evaluated in the dry season 2007, rainy season 2007 and rainy season 2008 along with about 28 test-cross hybrids and gave dry forage yield of 12.1, 9.2 and 7.8 tons ha^{-1} respectively and the best check SSG 59-3 yielded 15.5, 10.2 and 9.7 tons ha^{-1} dry forage in these trials. Again in summer 2009, these three varieties were evaluated with seven test-hybrids and standard checks in a trial which recorded trial mean of 8.6 tons ha^{-1} dry forage and SSG 59-3 had 10.4 tons of dry forage ha^{-1}. On the basis of overall mean of the six-environment data, ICMV 05555 recorded highest dry forage yield of 10.7 tons ha^{-1} followed by ICMV 05777 (10.0 tons ha^{-1}) which were comparable to the overall performance of the best check SSG 59-3 (11.1 tons ha^{-1}).

ICMV 05555 was bred by random mating 10 progenies, 1 of which was derived from germplasm accession IP 15352 (India) and 9 were derived from IP 22269 (India). This variety has short height, thin stem and high tillering potential. ICMV 05777 was developed from IP 6073, a landrace from Central African Republic. ICMV 05777 is a tall, thick stemmed variety with good tillering potential.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.2 PM Virulence changes in Indian pearl millet downy mildew populations characterized

Achievement of Output Target:
100%
Virulence change in downy mildew pathogen, *Sclerospora graminicola,* is an ongoing process, largely influenced by changes in cultivars and weather variables. Therefore, this has to be continuously monitored through on-farm disease survey and multilocation *virulence* nursery. The new isolates are collected and characterized using differential hosts and molecular markers to identify new *virulences.* It is planned to be reported again in 2011 and subsequently every 3-5 years.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Seed Companies

Progress/Results:
Isolates of *Sclerospora graminicola*, the pearl millet downy mildew (DM) pathogen, collected from highly susceptible pearl millet hybrids during on-farm surveys in different states of India are characterized for pathogenic variation to monitor virulence change in the pathogen population. Highly virulent isolates thus identified from different states are used for screening germplasm and breeding lines for identifying new sources of resistance and developing DM-resistant hybrid parental lines and hybrids.

Virulence diversity was studied in *S. graminicola* populations (54 isolates) collected from nine Indian states (Andhra Pradesh- 5; Maharashtra- 3; Karnataka- 1; Rajasthan- 16; Gujarat- 5; New Delhi- 1; Haryana- 1; Uttar Pradesh-21 and Tamil Nadu-1) during 1992-2008. Pathogenic variation was studied by their reaction on seven host differential lines (P 7-4, P310-17, 700651, 7042R, 852B, IP 18292 and IP 18293) in the greenhouse. For this, pot-grown seedlings of pearl millet lines were spray-inoculated at the coleoptile stage with sporangial suspensions of the test isolates. The inoculated seedlings were incubated at 20ºC and >90% RH for 20 h, and then transferred to a greenhouse bench at 25 ºC under misting (leaf wetness) for disease development. Downy mildew incidence was recorded 14 days after inoculation as percent infected plants. Quantitative differences in virulence of the isolates were assessed by calculating virulence index (disease incidence × latent period^{-1}).

Significant variation was observed for downy mildew incidence, latent period and virulence index among the test isolates. Based on their reaction type on host differentials, 54 isolates formed 20 pathogenic groups. Group 1 comprising 20 isolates was most virulent and the isolates belonging to this group were virulent on all the seven differentials. Group 19 represented by isolate Sg 468 (from Rajasthan) was the least virulent and could not cause >10% incidence in any of the seven differentials. A dendrogram (generated by the average linkage cluster analysis) of virulence index clustered the 54 isolates into five major groups. Based on virulence index, group I comprising 7 isolates (3 from Rajasthan, 2 from Uttar Pradesh and 1 each from Gujarat and Andhra Pradesh) with >14 mean virulence index across differentials was most virulent.

Thirty-seven SSR primers developed for genetic diversity studies in sorghum downy mildew pathogen (*Peronosclerospora sorghi*) were used to assess allelic diversity in *S. graminicola*. PCR was carried out to amplify SSR loci using DNA of the 54 isolates of *S. graminicola* and one isolate of *P. sorghi*. Of the 37 SSRs used to study allelic variation, only 20 could amplify reproducible fragments in the isolates tested. However, none of them was polymorphic, hence we could not detect allelic variation/genetic diversity in the *S. graminicola* isolates. Therefore, there is a need to develop SSR markers specifically for *S. graminicola* for genetic diversity studies.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.3 PM At least five each of blast and rust resistance sources identified

Achievement of Output Target:
80%
Some more breeding lines and *germplasm* accessions are being screened for rust during the postrainy 2009-10. This research would continue to identify new and more sources of resistance and eventually sources of stable resistance through *multilocation* testing. In the event of detection of variability in the blast and rust pathogens, ore efforts would be required to identify resistance to single and or multiple *pathotypes.*

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Leaf blast caused by *Pyricularia grisea* has emerged as a major disease limiting pearl millet production of both forage and grain hybrids in India during the past few years. This disease becomes most severe during humid weather conditions, especially with dense plant stands. On-farm surveys conducted during the rainy season in Rajasthan, Uttar Pradesh and Gujarat have revealed increased incidence of blast in several hybrids in the recent past. Rust disease caused by the fungus *Puccinia substriata* var. *indica* is another major disease affecting both forage and grain production in pearl millet. Rust has been observed, particularly during the late rainy season and post-rainy season crops in India. Therefore, we standardized greenhouse and field screening techniques to evaluate pearl millet lines to identify sources of blast and/or rust resistance.

Identification of blast resistance: One hundred twenty-six designated B-lines were evaluated for blast resistance in the disease nursery during the rainy season 2008 and selected lines were further screened in the greenhouse in 2009 to confirm their field resistance. The blast scores ranged from 2.0 to 9.0 on a 1-9 scale compared to a score of 7.0 to 9.0 in the susceptible checks (ICMB 89111 and ICMB 95444). Nine lines (ICMB 93222, -97222, -01333, -01777, -02111, -02444, -02777, -03444 and -03999) were found resistant (score 2.0-3.0), 55 moderately resistant (score 3.1-5.0), 34 susceptible (score 5.1-7.0) and the remaining 28 highly susceptible (score >7.0). The above nine resistant lines were also resistant to downy mildew (DM incidence ≤10) in the downy mildew sick field. The lines found resistant to blast in the field screen were further evaluated under greenhouse conditions to confirm their resistance. All the selected lines (except ICMB 03444) were resistant to blast (<3.0 scores) confirming their field resistance.

Identification of rust resistance: A total of 214 advanced breeding lines, including 126 designated B-lines, 23 designated R-lines and 65 potential R-lines were evaluated for rust resistance in the disease nursery during postrainy season (November- March) 2008-09 and the resistant lines were further screened in the greenhouse to confirm their resistance. Rust severity on top 4 leaves and lower leaves was recorded separately. Eight lines (1 B-line and 7 R-lines) with ≤10% rust severity (both on top and lower leaves) under field screen were further screened in the greenhouse along with susceptible check ICMB 89111, and ICML 11 (reported to be rust resistant) to confirm their field resistance. The selected B-line, ICMB 96222 had only 2% rust severity in the greenhouse screen, whereas hypersensitive response (highly resistant reaction) was observed in 3 R-lines (ICMR 0699, ICMP 451-P8, ICMP 451-P6). ICMB 96222, ICMR 06999 and ICMP 451 have diverse parentage, whereas ICMP 451-P6 and ICMP 451-P8 are selections from LCSN 72-1-2-1-1.

Resistance to multiple diseases: Three lines (ICMB 02111, ICMB 02777 and ICMB 93222) were resistant to three major diseases – blast, rust and DM in the field screen. The blast resistant lines were also resistant to DM in the field screen. ICMR 06999 and ICMP 451-P6 were resistant to rust and DM.

Output target 2009 5.1.4 PM Two PhD scholars complete their dissertation research

Achievement of Output Target:
100%

Participating Countries:
India and the Czech Republic

Participating Partners:
The Andhra University, Visakhapatnam, Andhra Pradesh, India; Tamil Nadu Agricultural University, Coimbatore, Tamilnadu, India; Central University of Hyderabad, Hyderabad, Andhra Pradesh, India; and The Charles University Prague, Czech Republic

Progress/Results:
Mr. K. Baskaran successfully defended his PhD thesis entitled "Characterizing responses to population improvement for grain and stover-yield related traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.] using SSR markers" following its submission to Tamil Nadu Agricultural University in January 2007. Ms. P. Varalakshmi successfully defended her PhD thesis "Studies on the genetics of some phenotypic, isozyme and microsatellite markers and gene tagging in pearl millet, *Pennisetum glaucum* (L.) R. Br.", following its submission to the Andhra University in November 2007, Mr. V. Vengadessan successfully defended his PhD thesis entitled "Genetic and QTL analyses of sink size traits in pearl millet [*Penisetum glaucum* (L.) R. Br.]" following its submission to Tamil Nadu Agricultural University in March 2008. Finally, Ms. Jana Kholova successfully defended her PhD thesis entitled "Investigation of physiological traits putatively involved in terminal drought tolerance of pearl millet (*Pennisetum glaucum* (L.) R. Br.)" in September 2009 to The Charles University in Prague.

In addition, ICRISAT Research Scholars Ms. B. Ramana Kumari (Osmania University, Hyderabad), Mr. Sushil Kumar (Rajasthan Agricultural University, Bikaner) and Ms. Supriya (CCS Haryana Agricultural University, Hisar) are expected to complete their PhD thesis research projects on topics related to marker-assisted improvement of pearl millet during the course of 2010, while that of Mr. V. Rajaram (JNTU-Hyderabad) will be completed in 2011.

Output target 2010 5.1.1 PM At least 5 each of pearl millet seed and restorer parents adapted to arid conditions developed

Achievement of Output Target:
50%

Two promising restorer parent lines have been identified from testcross trials which would be evaluated further, and new potential seed and restorer parental lines have also been identified for further evaluation.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl Millet Improvement Project and its sub-centers

Progress/Results:
Hybrid parental lines with early maturity and high-tillering potential are desirable for successful pearl millet crop in arid conditions. Based on the test-cross trials conducted in arid environments in north-western India in the rainy season of 2009, two restorer lines viz. MRC S1-89-1-1-B-B-B-1 and MRC S1-9-1-1-B-B-B-B-1 were identified which produced superior hybrids with different seed parental lines.

To develop seed parents for arid zone, about 315 advanced seed parent progenies (S_4-S_7) derived from ICRISAT-CAZRI B–Composite (ICCZBC) were evaluated in a drought nursery during summer-2009, of which 70 were selected, with 14 of these flowering in 46-50 days (check 843B flowered in 47-49 days). Also, a nursery comprising of 49 advanced progenies (F_9-F_{11}) was evaluated in drought nursery of summer 2009, of which 21 were selected with 3 progenies flowering in 46-50 days and 6 progenies flowering in 51-55 days (check 843B flowered in 47 days and check 842B flowered in 50 days). A nursery of 144 promising extra-early seed parent progenies was also evaluated in rainy 2009, of which 35 progenies were selected. Of these, 18 progenies were found to flower in 41-45 days (check 843B flowered in 41 days and EEBC 407 flowered in 40 days).

For development of restorers with probable adaptation to arid zone, 74 early to extra-early progenies (S_7-S_{13}) and 854 progenies (S_3-S_6) derived from an extra-early R-composite were evaluated in rainy season of 2009. About 380 progenies were selected from these nurseries, of which 22 flowered in less than 45 days and 116 flowered in 46-50 days. The check H77/833-2 flowered in about 43 days and ICMR 356 flowered in about 49 days in these nurseries.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.2 PM Genetics of four diverse CMS systems documented

Achievement of Output Target:
50%
This output target is about the publication of journal articles from a PhD thesis submitted in 2005. An article on the genetics of A_1 CMS system was submitted for publication. The article on genetics of A_5 and Aegp CMS systems has been drafted and the populations to confirm the genetics of A_4 CMS system are being developed.

Participating Countries:
India

Participating Partners:
CCSHAU, Hisar

Progress/Results:
Inheritance of male sterility and fertility restoration of the A_1 system of cytoplasmic- nuclear male sterility in pearl millet was investigated, as part of a Ph.D. thesis, using 12 crosses among three diverse male sterile lines (A- lines) and four diverse restorers (R- lines) and evaluated in two different seasons. Individual plants from R- lines were used to make crosses. The re-analysis of the data on segregation pattern of male sterile (S) and male fertile (F) plants observed in F_2 and BC_1 was suggestive more likely of a single-gene control of male sterility and fertility restoration. However, a 3-gene model of male sterility/ fertility restoration where dominant alleles at any two of the three duplicate complimentary loci will lead to male fertility was not ruled out, nor was ruled out a 2-gene control with duplicate interaction. There was indication of variability even within a highly inbred R-line for fertility restoration gene(s). Depending on the genetic constitution of the R-lines at these loci, it was suggested that even the 3-gene model can lead to single-gene segregation ratios as observed in most of the F_2s and backcrosses, and 2-gene ratios as observed in a few F_2s and backcrosses. The research paper reporting these results has been submitted to Cereal Research Communications.

A manuscript reporting on genetics of A_5 and A_{egp} CMS systems has been drafted. The segregating generations are being developed using two CMS lines (A_4 cytoplasm) crossed each with 3 restorer parents to validate the results of a previous study on the inheritance of this CMS system.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.3 PM More than 30 scientists develop pearl millet research and development skills through an international training course

Achievement of Output Target:
The 2009 training course will likely be further postponed to 2011

Participating Countries:
India

Participating Partners:
None

Progress/Results:
The training course planned for 2009 will likely be postponed to 2011 due to lack of funding for 2010. Possible funding sources will be explored to support this course.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.4 PM More than 50 scientists participate in Pearl Millet Field Day and select more than 600 breeding lines

Achievement of Output Target:
Field Day 2010 will be held as per the schedule.

Output target 2010 5.1.5 PM Effect of putative QTLs identified for stover yield and quality on these traits in two genetic backgrounds assessed

No report provided

Output target 2011 5.1.1 PM At least 40 improved breeding lines with resistance to blast and rust (20 each) developed

Achievement of Output Target:
30%
Evaluation of advanced breeding lines to rust and blast- the two emerging diseases-will continue to identify those with acceptable levels of resistance to these and also to downy mildew.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
A total of 85 advanced breeding lines, including 20 designated R-lines and 65 potential R-lines were evaluated for blast resistance in the disease nursery during rainy season of 2008 and selected lines were screened in the greenhouse to confirm their field resistance. Of the 20 designated R-lines, one (ICMR 06222) was highly resistant, five (ICMR 06111, -06444, 06666, -07555 and -356) resistant, 13 moderately resistant, and one susceptible to blast in the field screen. Of the 65 potential R-lines, two were highly resistant, 28 resistant, 23 moderately resistant, nine susceptible and remaining three were highly susceptible to blast in field. The selected resistant lines were further evaluated in the greenhouse. Three designated R-lines (ICMR 06222, -06444 and -07555) and 14 potential R-lines were resistant to blast (<3.0 scores) confirming their field resistance to *P. grisea*.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2011 5.1.2 PM Recurrent selection response for stover quality assessed

No report provided

Output target 2011 5.1.3 PM Relationship between grain and stover yield heterosis and genetic diversity of parental lines documented

Achievement of Output Target:
40%
Evaluation of hybrids developed in set I (developed on the basis of molecular diversity among designated B- and R-lines) and in set II (developed on the basis of molecular diversity among promising B- and R- lines) is completed for grain and stover yield components in rainy season , with one more season (postrainy season , 2010) evaluation to be done.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
The efficiency of breeding high-yielding hybrids can be significantly enhanced with the formation of heterotic gene pools. A series of experiments has been planned to assess the relationship between molecular diversity and yield heterosis as a first step to initiate the heterotic pool formation. In 2008, 126 designated B-lines and 150 designated R-lines (set I) were analyzed for molecular diversity using 38 polymorphic markers (32 SSR and 6 EST), well distributed across all seven linkage groups. Diversity analysis of molecular data was carried out using DARwin 5.0 software. Based on the genetic distances from molecular data (276 B×R distance matrix and 150 R×R distance matrix), pedigree information, and days to 50% flowering, 23 hybrids (20 B×R and 3 R×R pairs) and 46 parental lines were evaluated at ICRISAT-Patancheru during 2009 rainy season. Data on grain and stover yield and agronomic traits were recorded. Preliminary analysis revealed non-significant correlation (r = 0.30) between molecular diversity and grain yield heterosis. The same trial was planted in postrainy season of 2009 at Patancheru in a RCBD with three replications, with hybrids and parental lines planted side-by-side as the blocks in each replication. Due to some germination problem, this trial was re-sown. This re-sown trial flowered during high air temperatures prevalent during postrainy season at Patancheru, which resulted into poor seed set in most of the parents. Now this trial will be evaluated in postrainy season of 2010.

In set II, 88 potential B-lines and 78 potential R-lines were analyzed for molecular diversity using allelic data from 28 pearl millet SSR markers. Diversity analysis was carried out using DARwin 5.0 software. Dissimilarity matrices calculated for pairs of B-lines, R-lines and B-lines × R-lines, using simple matching revealed genetic distance range of 0.17 to 0.96 between B- and R-lines. For B-lines, the genetic distance between pairs ranged between 0.04 and 0.85 with a mean of 0.50, while the genetic distance between pairs of R-lines ranged between 0.14 and 0.96 with a mean of 0.67. The hierarchical cluster analysis following weighted neighbor-joining method delineated the B-lines and R-lines into two major groups. Nearly all of the R-lines grouped into a single large cluster (with several distinct sub-clusters) and all of the B-lines were distributed across one single cluster (with several sub-clusters). In addition to the two major B- and R- lines clusters, a few B- and R-lines that shared common pedigree formed two small clusters separately. Based on the genetic distance from molecular data (166 B x R distance matrix), pedigree information and days to flowering, 29 B x R pairs of parental combinations were selected and hybrid seed was produced. These 29 hybrids along with their parental lines were evaluated in rainy season of 2009 at ICRISAT-Patancheru in a RCBD with three replications, with hybrids and parental lines planted side-by-side as separate blocks in each replication. Data on grain and stover yield and agronomic traits were recorded. Preliminary analysis revealed non-significant correlation (r = 0.19) between molecular diversity and grain yield heterosis. The grain yield of the hybrids in the trial ranged from 1185 kg ha^{-1} to 2485 kg ha^{-1}. The best control hybrid 9444 had 2519 kg ha^{-1} grain yield.

Output target 2012 5.1.1 PM Avirulence gene mapping and SSR marker development in *Sclerospora graminicola* completed (RS)

This work to be initiated in 2010

Output target 2012 5.1.2 PM Information on epidemiology and inheritance of resistance to blast and rust in pearl millet generated

Achievement of Output Target:
25%
Inheritance of blast resistance has been studied and needs further confirmation. Screening techniques for blast and rust have been established based on epidemiological parameters. More epidemiological studies are needed to understand the role of alternate/collateral hosts in disease perpetuation and as a source of primary inoculum. Inheritance of rust resistance needs to be studies further.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Epidemiology of blast: Preliminary studies revealed that 10-day-old seedlings could be artificially infected by the blast pathogen, *Pyricularia grisea*. The disease development is favored by moderate temperature (25-30 °C) and high humidity (>90% RH). Artificially inoculated seedlings exposed to leaf wetness for 7 days enhanced disease development in the greenhouse. The incubation period (symptom appearance) is about 4 days and latent period (spore to spore cycle) takes about 7 days. The role of grasses in perpetuation of disease and a source of primary inoculum needs to be investigated.

Epidemiology of rust: Through preliminary studies, we confirmed the role of egg plant (*Solanum melongena*) as an alternate host of the pearl millet rust pathogen *Puccinia substriata* var. *penicillariae*. Egg plants, when inoculated with teliospores collected from pearl millet, developed aecial cups and aeciospores. These aeciospores when inoculated on to pearl millet produced rust pustules and urediniospores. Pot-grown 10-day-old seedlings could be artificially inoculated with urediniospores and symptoms develop 8 days after inoculation. Moderate temperature (20-25 °C), high humidity (>90% RH) and leaf wetness for 4-6 days favor rust development. More studies are needed to understand the role of other alternate and collateral hosts as source of primary inoculum.

Inheritance of blast resistance: Two each of blast-susceptible lines (ICMB 89111 and ICMB 95444) were crossed with each of the two resistant lines (ICMR 06222 and ICMR 07555) to develop segregating populations to study inheritance of blast resistance in pearl millet. The parents, F_1, F_2, BC_1F_1P1 (backcross with susceptible parent) and BC_1F_1P2 (backcross with resistant parent) generations of each of the four crosses were screened in greenhouse as well as in field using screening techniques standardized at ICRISAT. The data are being analyzed and segregation patterns in some of the populations are to be confirmed.

Inheritance of rust resistance: A linkage map with 229 DArT and 57 SSR marker loci was constructed for a mapping population of 168 F_7 RILs segregating for rust resistance from cross 81B-P6 (susceptible) × ICMP 451-P8 (resistant). In a greenhouse screen of RILs, rust severity ranged from 0 to 95%, with 99% heritability. These values are being used for QTL analysis.

Output target 2012 5.1.4 PM Two medium-maturity elite composites with combined resistance to DM, blast and rust developed.

Achievement of Output Target:
10%
Promising hybrid lines with multiple resistance to DM and blast have been identified for utilization to develop composite with combined resistance to DM and blast.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Downy mildew (DM) affects pearl millet crop across all the regions and based on the recent discussions with the partners of Pearl millet Hybrid Parents Research Consortium it has been realized that blast incidence has increased at an alarming rate, particularly on commercial hybrids in several states of India. Though rust also appears in some of the areas and affects mostly postrainy season crop, still it seems to be disease of secondary importance. Thus the research thrust has been revised with high priority to DM and blast. Efforts are under way to develop a DM and blast resistant B-Composite and a DM and blast resistant R-composite. Working in this direction, eight designated seed parental lines (ICMB 93222, -97222, -01333, -01777, -02111, -02444, -02777, and -03999) found resistant (score 2.0-3.0) to blast in the field screen and under green house conditions were also found resistant to downy mildew (DM incidence ≤10) in the downy mildew sick field at Patancheru. These lines had been earlier screened for DM resistance, and found resistant to at least two of the five diverse pathotypes. These multiple resistant lines to blast and DM will be utilized to develop a DM and blast resistant B-Composite (DMBRBC) with combined resistance to DM and blast. Also, three designated R-lines (ICMR 06222, -06444 and -07555) and 14 potential R-lines have been found resistant to blast (<3.0 scores) in the field screen and green house conditions. These identified blast resistant lines will be screened against various DM pathotypes and the lines found resistant would be utilized to develop a DM and blast resistant R-Composite (DMBRRC) with combined resistance to DM and blast. The screening of additional promising breeding lines for DM and blast will be continued to identify lines resistant to both diseases for use in introgression to diversify the genetic base of these composites.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Pigeonpea

Output target 2009 5.1.1 PP At least 15 high- yielding pigeonpea hybrids and a short-duration determinate male-sterile line made available to NARS partners

Achievement of Output Target:
100%
More than 140 hybrids in extra-short, short and medium-maturity groups were evaluated and more than 70 new restorers and 12 new maintainers have been identified so far. We have made available 17 pigeonpea hybrids to various private seed companies and NARS partners.

Participating Countries:
India

Participating Partners:
Indian NARS (Public and Private Sector)

Progress/Results:
During rainy season 2008, a total of 43 hybrids in extra-short, short and medium maturity duration were evaluated for identification of new fertility restorers and male-sterility maintainers in five trials with two replications at Patancheru. All the trials were severely damaged first by water-logging and then by *Maruca* and pod-sucking bugs. These trials could not be analyzed statistically due to excessive plant loss. However, the fertility restoration data were recorded. Out of 43 hybrids, 28 were fertile (90-100% fertility restoration), four (ICPH 2460, ICPH 3313, ICPH 3629, ICPH 3171) maintained male-sterility (pollen sterility >80%) and 11 segregated for male fertility and sterility (21-89% fertility restoration). For development of new A- lines, single plant selections were made in the F_1s of four hybrids listed above for pollen sterility, plant type and important yield contributing traits like number of primary and secondary branches. These plants were backcrossed on single plant basis with their respective recurrent parents. In this maturity group, 29 new restorers were also identified on the basis of their fertility restoration in the hybrids. A total of 75 R- lines identified during previous and current seasons were grown under nylon nets. These lines were selfed and will be tested again for their fertility restoration in different cross combination during 2009. These lines will also be evaluated for *Fusarium* wilt, sterility mosaic (in disease screening nursery) and *Phytophthora* blight (field screening) resistance. Hence, in the past four years, more than 140 A_4-based hybrids were evaluated for male fertility restorers and maintainers. Currently, for A_4 system, we have 75 fertility restorers (with more than 90% fertility restoration), and 12 maintainers.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India

Output target 2009 5.1.2 PP Elite pigeonpea hybrid parents characterized for important agronomic traits and molecular diversity

Achievement of Output Target:
100%
More than 50 A-/B- lines, and more than 60 R- lines have been characterized morphologically for important agronomic traits. Molecular diversity study was completed with 41 SSR markers.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
Morphological diversity: A total of 55 B- lines were characterized during the rainy season 2009 at Patancheru. Many of these lines had been characterized during the 2007. Data were recorded for days to flower and days to maturity, seeds pod[-1], 100-seed mass, and grain yield in replicated trials. There was good variability for these traits. These lines were grown in disease sick plot and disease reaction of these lines was recorded for *Fusarium* wilt and sterility mosaic diseases. In the extra-short maturity determinate (DT) group, the range of variation for seed yield was from 310 to 1194 kg ha^{-1}. Other important traits such as days to 50% flowering and 75% maturity ranged from 60 to 70 days and 90 to 100 days, respectively. Plant height ranged from 60 to 100 cm, seeds pod[-1] from 3.7 to 4.7, 100-seed mass from 7.8 to 12.8 g, wilt incidence from 0 to 95%, and sterility mosaic incidence from 0 to 96%. In the extra short-maturity non-determinate (NDT) group the

variation for grain yield ranged between 376 and 1544 kg ha^{-1}. The variation for other important traits such as days to 50% flowering and 75% maturity ranged from 64 to 82 days and 92 to 120 days, respectively. Plant height ranged from 88 to 142 cm, seeds pod^{-1} from 3.9 to 4.8, 100-seed mass from 7.3 to 10.7 g, wilt incidence ranged from 76 to 100%, and sterility mosaic incidence from 0 to 59%. In short duration determinate (DT) group the variation for grain yield ranged from 564 and 1469 kg ha^{-1}, days to 50% flowering and 75% maturity ranged from 74 to 84 days and 108 to 125 days, respectively. Plant height ranged from 82 to 110 cm, seeds pod^{-1} from 3.8 to 5.5, 100-seed mass from 9.0 to 12.3 g, wilt incidence from 12 to 100%, and sterility mosaic incidence from 0 to 77%. In the short-maturity non-determinate (NDT) group the variation for grain yield ranged between 89 and 1507 kg ha^{-1}, days to 50% flowering and 75% maturity ranged from 61 to 89 days and 92 to 125 days, respectively. Plant height ranged from 60 to 155 cm, seeds pod^{-1} from 4.2 to 4.5, 100-seed mass from 7.9 to 10.6 g, wilt incidence ranged from 86 to 100%, and sterility mosaic incidence from 0 to 39%. The medium-duration group was classified into 'Maruti' maturity group (95 to 110 days to flower) and 'Asha' maturity group (120 to 135 days to flower). In Maruti maturity group trial, grain yield ranged from 619 to 2120 kg ha^{-1}, days to 50% flowering from 96 to 120 days, days to 75% maturity from 150 to 172 days, plant height from 105 to 175 cm, seeds pod^{-1} from 3.2 to 4.9, and 100-seed mass from 6.0 to 13.2 g. Disease reaction was also recorded. Wilt incidence ranged from 0 to 100%, and sterility mosaic incidence from 0 to 87%. In Asha maturity group, grain yield ranged from 875 and 2253 kg ha^{-1}, days to 50% flowering and 75% maturity ranged from 112 to 142 days and 163 to 203 days, respectively. Plant height ranged from 135 to 218 cm, seeds pod^{-1} from 3.9 to 5.2, 100-seed mass from 7.3 to 17.1 g, wilt incidence from 0 to 100%, and sterility mosaic incidence from 0 to 13%. These well characterized lines will be made available to NARS and consortium partners for use in their parental line and hybrid breeding programs.

A total of 135 R- lines were also characterized for important agronomic traits. These R- lines were also categorized into extra-short duration, short duration and medium duration. In extra-short duration group, the seed yield ranged from 731 to 1459 kg ha^{-1}. Variation for days to flower was 62-85 days, days to maturity from 98 to 125 days, plant height from 95 to162 cm, seeds pod^{-1} from 3.7 to 4.5, and 100-seed mass from 7.6 to 11.0 g. Disease reaction was also recorded. Wilt incidence ranged from 44 to 100%, and sterility mosaic incidence from 0 to 88%. In short-maturity group seed yield ranged from 1061 to 2012 kg ha^{-1}, days to 50% flowering from 80 to 85 days, days to 75% maturity from 110 to 125 days, plant height from 110 to 150 cm, seeds pod^{-1} from 3.9 to 4.6, and 100-seed mass from 7.8 to 9.9 g. Most of the lines were susceptible to wilt (range 80 to 100%). Sterility mosaic disease ranged from 0 to 86%. There was not much variation in terms of days to flower and maturity between medium and long maturity groups, hence all these R- lines were treated in medium maturity group. In this group, grain yield ranged between 690 and 2299 kg ha^{-1}, and days to 50% flowering and 75% maturity from 115 to 139 days and 172 to 193 days, respectively. Plant height ranged from 135 to 222 cm, seeds pod^{-1} from 3.8 to 5.3, 100-seed mass from 7.5 to 16.9 g, wilt incidence from 0 to 85%, and sterility mosaic incidence from 0 to 29%.

Molecular diversity: To characterize 159 lines (37 A-, 38 B- and 84 R-) of pigeonpea hybrids, a set of 148 SSRs was utilized. Of these, 41 markers showed polymorphism among 159 lines. Across the lines surveyed, these markers detected 2-6 alleles (average 3) with PIC value in the range of 0.01- 0.80 (average 0.41) per marker. Among different groups, the SSR markers showed a higher PIC value among 38 B-lines (0.39), followed by R-lines (0.37) and the least in A-lines (0.34).

To understand the genetic relationships among and within A-, B- and R- lines, the genotyping data were scored as a 0-1 matrix for the presence or absence of the alleles to analyze the genetic similarity. Two main clusters were observed that could be classified into two sub-clusters. Cluster I contained the majority of A- (34 out of 37) and 14 out of 38 B-lines, while cluster II contained the majority of R- (68 out of 84) and 24 out of 38 B-lines. Although with the available genotyping data we could not be able to differentiate clearly among A-, B- and R-lines, it showed that B-lines are more close to the R- lines.

Output target 2010 5.1.1 PP Consensus molecular marker and genetic linkage maps developed and shared with partners

Achievement of Output Target:
70%

Participating Countries:
USA, Australia

Participating Partners:
University of California-Davis; DArT Pty Ltd

Progress/Results:
Development of microsatellites from Bacterial Artificial Chromosome (BAC) end sequences (BES): In collaboration with University of California, Davis (Doug Cook), a total of 87,590 pigeonpea BAC-end sequences (BES) were generated. These represented 56.5 Mb of genome, and were surveyed for the presence of microsatellites using MIcroSatellite (*MISA*) search module. As a result, 18,149 pigeonpea microsatellites (1 SSR per 3.11 Kb) were identified. Primer pairs were designed for 6,590 SSRs, however, only 3,072 were selected for synthesis and were tested for amplification. As a result 3,026 primer pairs produced scorable amplification on 24 pigeonpea genotypes that are parents of different mapping populations segregating for *Fusarium* wilt (FW), sterility mosaic (SM) and water logging.

Gene based markers: An assembly of 454/FLX and Sanger sequence reads resulting in 127,754 tentative unique sequences (TUS) unigenes with an average length of 226 bp, were screened to evaluate the presence of SSR motifs using *MISA* search tool. This resulted in the identification of 41,899 (32.7%) sequences containing 50,566 SSRs with an average of one SSR per 570 bp. Of these 41,899 sequences, 6,997 (16.6 %) sequences contained more than one SSR and 6,352 (15.1%) were compound SSRs that have more than one repeat type. Primer pairs were designed for 12,377 SSRs including mononucleotide SSRs. A total of 8,023 primer pairs were considered for validation after excluding the primers for mononucleotide and compound SSRs.

SSR-enriched library: Several genomic DNA libraries enriched for five SSR repeat motifs (CT, TG, AG, AAG, and TCG) were generated from Asha variety using bead capture enrichment protocol. Initially, 1,728 clones were picked from two libraries and 82 clones were sequenced. This pilot experiment provided 36 SSRs from which 23 primer pairs were synthesized of which 16 provided scorable amplification products. Screening of 40 elite genotypes with these 16 markers indicated moderate polymorphism information content (PIC)

values in the range of 0.05 to 0.55 with an average of 0.32 per marker. These results have been published in Plant Breeding (Saxena et al. 2009).

Development of genetic maps

A total of 554 DArT markers were detected in a pigeonpea mapping experiment using a F_2 mapping population of 72 progenies which were derived from an interspecific cross of ICP 28 (*Cajanus cajan*) × ICPW 94 (*Cajanus scarabaeoides*). Two groups of genetic maps were generated using DArT markers. A total of 121 unique DArT maternal markers were placed on the maternal linkage map. A total of 166 unique DArT paternal markers were placed on the paternal linkage map. The length of these two maps covered 437.3 cM and 648.8 cM, respectively.

In addition to above, genotyping of different mapping populations (inter- specific and intra- specific) with polymorphic markers as mentioned above is in progress.

Special Project Funding:
Pigeonpea Genomics Initiative of ICAR; Generation Challenge Programme; Department of Biotechnology (Govt. of India)

Output target 2010 5.1.2 PP At least three short-duration determinate male- sterile lines and 10 hybrids made available to NARS partners

Achievement of Output Target:
100%

Participating Countries:
India, Myanmar and Brazil

Participating Partners:
NARS and Private Sector from India, Myanmar and Brazil

Progress/Results:
During 2009, a total of four determinate male-sterile lines were shared with 11 private seed companies, and NARS partners from India, Myanmar and Brazil. Out of these four lines, ICPA/B 2039 belonged to early-maturity group. This line was in BC_{12} generation. Rest of the three lines belonged to the medium-maturity group and had white/cream seed coat color. ICPA/B 2078 and ICPA/B 2101were in BC_5 generation, while ICPA 2040 was in BC_3 generation. During the same year, a total of 15 hybrids in extra-short, short and medium-maturity groups were made available to 12 private seed companies and NARS partners. All the hybrids in medium-maturity group recorded high resistance to wilt and sterility mosaic diseases. Some of these hybrids (ICPH 3313, ICPH 2671 and ICPH 2740) have been found promising.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India; Tropical Legumes II

Output target 2010 5.1.3 PP Two Masters students and 50 scientists and technicians from NARS and private sector trained in pigeonpea breeding

Achievement of Output Target:
90%
Target for capacity building has been fully achieved for scientists and technicians. One masters student is pursuing her degree in hybrid pigeonpea breeding.

Participating Countries:
India

Participating Partners:
Indian NARS (Public and Private Sector)

Progress/Results:
ICRISAT scientists have been involved in training and capacity building of its research partners. During 2008/09 a total of 418 people were trained at ICRISAT, which included 50 scientists and 368 farmers. Also, a total of 439 copies of information bulletins/books/leaflets on hybrid seed production technology and ICM were distributed in various training programs conducted. ICRISAT is training one female student from Myanmar in hybrid breeding. The registration program was delayed. She is expected to finish her masters program by 2011. Instead of a second masters student, ICRISAT is training two Ph.D. students in hybrid pigeonpea breeding and biotechnology. One Ph.D. student is expected to complete his program by 2010.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India

Output target 2011 5.1.1 PP Seven medium-duration male-sterile lines made available to NARS and private sector for use in hybrid development

Achievement of Output Target:
80%
Six male-sterile lines were developed and made available to NARS and private sector.

Participating Countries:
India, Myanmar and Brazil

Participating Partners:
NARS (Public and Private Sector) from India, Myanmar and Brazil

Progress/Results:
During 2009, a total of six (ICPA 2042, ICPA 2043 and ICPA 2050 in BC_6 generation; ICPA 2047, ICPA 2092 and ICPA 2098 in BC_5 generation) medium-maturity male sterile lines were made available to eight private seed companies and NARS partners from India, Myanmar and Brazil. All these lines recorded moderate to high (average disease incidence < 20% on 1-9 scale) levels of resistance to wilt and sterility mosaic diseases. These lines are being used by private seed companies and NARS partners for generating experimental hybrids.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India; Tropical Legumes II

Output target 2011 5.1.2 PP One PhD scholar and 35 scientists and technicians from NARS and private seed sector trained in pigeonpea breeding

Achievement of Output Target:
90%
Target for capacity building has been fully achieved for scientists and technicians. One Ph.D student has obtained degree from Marathwada Agricultural University (MAU), Parbhani. One masters and two Ph.D students are pursuing their degree programs in hybrid pigeonpea breeding.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
ICRISAT scientists have been involved in training and capacity building of its research partners. In the month of July, 2008 under PHPRC, ICRISAT organized a training program for 23 Seed Production Officers on hybrid seed production program at ICRISAT. Training was also given to Seed Production Officers at Jawarharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Jabalpur. Apart from this, a total of 511 people were trained at ICRISAT during 2008/2009, which included 86 scientists, 57 seed production officers and 368 farmers. Also, a total of 439 copies of information bulletins/books/leaflets on hybrid seed production technology and integrated crop management were distributed in various training programs conducted. ICRISAT is training one female student from Myanmar in hybrid breeding. In addition, one Ph.D student has obtained his Ph.D degree from MAU, Parbhani. Two more Ph.D students are pursuing their research programs in hybrid pigeonpea breeding and biotechnology.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India

Output target 2012 5.1.1 PP Five medium-duration vegetable type A_4 system CMS lines, and eight high-yielding medium-duration vegetable type restoree lines developed with resistance to *Fusarium wilt and/or sterility mosaic disease(s)*

Achievement of Output Target:
20%
Three CMS lines are in initial backcross generations.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
Vegetable type A_4 system CMS lines with African nuclear background are being developed. During 2008, three CMS lines (ICPA 2101, ICPA 2050, and ICPA 2043) were used for making crosses with African origin vegetable type lines. Two crosses ICPA 2043 X ICP 12026, and ICPA 2043 X ICP 7201 maintained male sterility. The F_{1s} were back-crossed to the respective male parents for introgression of CMS trait in vegetable type line of African origin (ICP 12026 and ICP 7201). The BC_1 of these cross is being grown during 2009 rainy season in wilt-free plot for further backcrossing with the respective recurrent parents. In BC_1 of the ICPA 2043 X ICP 12026 cross, a total of 260 plants are being grown for backcrossing, while in the cross ICPA 2043 X ICP 7201 a total of 100 plants are being grown for backcrossing. Much of the plant population was lost due to severe water-logging and *Phytophthora* blight attack. In addition, a total of 28 vegetable type lines of African origin restored male fertility (> 90% fertility restoration). A sub-set of these A/B & R- lines will be screened for resistance to wilt and sterility mosaic diseases during 2010 rainy season.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India; Tropical Legumes II

Output target 2012 5.1.2 PP Molecular marker(s) for fertility restorer gene(s) identified in pigeonpea

Nothing to report

Output 5.2: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeon pea with improved tolerance to abiotic stresses, made available to partners with associated knowledge and capacity building in SAT Asia

Output target 2009 5.2.1 SOPM Physiological mechanisms explaining the stay-green trait dissected in sorghum near-isogenic lines with stay-green QTLs

Achievement of Output Target:
100%
Although the output target has been fully achieved, we are still repeating some experiments and there are more details about some of the traits.

Participating Countries:
Australia, India

Participating Partners:
NRCS, University of Queensland, Queensland Department of Plant Industry and Fisheries

Progress/Results:
One of the hypotheses about stay-green trait is possible differences in the pattern of water use, with stay-green materials likely to be those using a relatively lower proportion of water during the pre-anthesis period, to favor more water availability for grain filling. In the genetic background of S 35 and R 16, we found a clear negative relationship across the lines, between the amount of water taken before anthesis and that taken after anthesis, showing that genotypes taking up more water before anthesis took up less water after anthesis.

Another factor to explain the maintenance of green leaves under residual moisture is the capacity to extract water from the soil profile. The lysimetric system in which the entries were tested allowed us to assess this possibility. In S35 background, total water extraction from the tubes varied from 10.7 L plant^{-1} to 14.6 L plant^{-1} with S35 having a water extraction of 12.8 plant^{-1}. This was relatively low compared to a range of germplasm in that was tested simultaneously (reported in MTP project 2, range between 10.2 to 15.3 L plant^{-1}). So, in S35 background, many QTL introgression lines conferred an advantage for water extraction, especially with Stg1, StgB and Stg3. In R16 background, total water extraction from the tubes varied from 10.2 L plant^{-1} to 14.8 L plant^{-1} with R16 having a water extraction of 14.3 plant^{-1}. The data showed that R16 background had a fairly high capacity to extract water from the tubes. In this background, none of the stay-green introgression lines had any increase in water extraction compared to R16, although several Stg1 and Stg3 introgression lines had water extraction at the level of R16. These data showed that some of the QTL may contribute to increasing water extraction, but this depends on the genetic background in which they are introgressed. We can speculate that Stg1 and Stg3 would have a role to play in increasing water extraction, provided they are not introgressed in a genetic background already endowed with similar attributes.

Finally, stay-green differences could be related to differences in the water productivity. Genotypes with such higher productivity would be able to produce similar biomass than a less efficient line at same water cost. Therefore, the lysimetric experiment also gave the opportunity to assess transpiration efficiency (TE) on a longer term basis, i.e. from about 4 weeks after sowing up until maturity. TE value varied between 3.69 g kg^{-1} to 5.49 g kg^{-1} water transpired in R16 background. TE varied between 4.35 g kg^{-1} to 6.08 g kg^{-1} water transpired in S35 background. So, generally, introgression lines in S35 background had higher TE values. This was likely because S35 had fairly high TE level (5.52 g kg^{-1}) compared to a large range of germplasm (data reported in MTP project 2). In S35 background, few stay-green QTL introgression lines had TE above S35 and the differences were moderate. Yet, introgression lines with Stg 3, Stg4 or Stg B had fairly high TE equal or superior to S35. In R16 background, which had moderate to low TE level (4.33 g kg^{-1}) compared to germplasm, most Stg B, and Stg3 and few Stg4 introgression lines had higher TE, equal or superior to R16. This showed once again clearly the importance of the genetic background for a given QTL to confer TE advantage.

Special Project Funding:
ACIAR

Output target 2009/2011 5.2.2 SOPM Dual-purpose stay- green and foliar disease resistant forage/sweet sorghum hybrid parents developed (partly associated with the SLP SWEP)

Achievement of output target:
100%
From the evaluation of hybrids and hybrid parents, promising parents (A/B-lines and R-lines) that give heterotic hybrids have been identified

Participating Countries:
India

Participating Partners:
Indian NARS and Private sector

Progress/Results:
Sweet sorghum preliminary hybrid nursery: A total of 2545 sweet sorghum hybrids were evaluated in augmented block design during the 2009 rainy season along with the controls SSV 84 and CSH 22SS. Based on Brix% (>14.5) and biomass score of <2 (taken on a 1 to 5 scale, where 1+ high biomass and 5= poor biomass), a total of 571 hybrids were selected and are being multiplied during the 2009 postrainy season for multilocation evaluation during rainy season 2010.

Sweet sorghum elite varieties/restorer line trial (SSEVRT): A total of 23 varieties/restorers lines selected from the sweet sorghum advanced varieties and restorer lines trial during the 2008 rainy season were evaluated in SSEVRT during the 2008 postrainy season along with the control SSV 84 in RCBD with three replications. The entries SP 4495, SP4484-2, SP 4511-3, SPV 422, SP 4511-2, SP 4484-3, and SP 4504-1 with sugar yield ranging from 0.5 to 0.9 t ha^{-1} were significantly superior to the control SSV 84 (0.2 t ha^{-1}). Among these lines, the grain yield varied from 1.9 to 4.0 t ha^{-1} (SSV 84: 2.8 t ha^{-1}) and Brix% from 11.5 to 15.9 (SSV 84: 8.6).

Sweet sorghum advance hybrid trial (SSAHT): A total of 53 hybrids selected from preliminary hybrid trial previously were evaluated in SSAHT during the 2008 postrainy season along with the controls SSV 84, CSH 22SS and CSH 25. Compared to the best performing control CSH 22SS (0.4 t ha^{-1}) seven hybrids ICSA 675 x ICSV 700, ICSA 749 x ICSV 93046, (1.3 t ha^{-1} each), ICSA 38 x ICSV 700, ICSA 95 x SPV 1411, (1.2 t ha^{-1} each), ICSA 38 x ICSV 93046, ICSA 675 x ICSV 93046, ICSA 24001 x SSV 74 (1.1 t ha^{-1} each) were significantly superior for sugar yield. Among these seven hybrids, grain yield ranged from 1.8 to 4.3 t ha^{-1} (CSH 22SS; 4.5 t ha^{-1}) and Brix% from 12 to 15.3 (CSH 22SS; 8.8).

Sweet sorghum elite hybrid trial (SSEHT): A total of 16 hybrids selected from advanced hybrids trials evaluated during the 2008 rainy season were evaluated in SSEHT during the 2009 rainy season along with the controls SSV 84 and CSH 22SS. The trial was conducted in RCBD in three replications. Compared to the best performing control CSH 22SS for sugar yield (3.1 t ha^{-1}), the hybrid ICSA 38 × AKSSV 22 (3.6 t ha^{-1}) was significantly superior while the hybrids ICSA 502 × SP 4487-1 (3.4 t ha^{-1}) and ICSA 675 × SP 4484-1 (3.4 t ha^{-1}) were numerically superior. Among these three hybrids, days to flowering varied from 84 to 91 days (CSH 22SS: 91 days), plant height from 3.5 to 3.7 m (CSH 22SS: 3.5 m) and Brix% from 17.8 to 20.5 (CSH 22SS: 20.4).

Sweet sorghum hybrid parental trial (SSHPT): The parental lines of hybrids in elite / advance hybrid trials that include 42 B-lines and 24 R-lines were evaluated in a hybrid parental lines trial along with the controls ICSB38, SSV74, SSV 84 and CSH 22SS during the postrainy season 2008 for terminal drought tolerance. Compared to the sugar yield of best performing control SSV 74 (0.3 t ha^{-1}), R-line SP 4511-2 (0.6 t ha^{-1}) was significantly superior for sugar yield and other R-lines SP 4495, ICSV 93046, ICSR 165, SP 4482-1, SP 4487-1 and SP 4484-1 with sugar yield ranging from 0.4 to 0.6 t ha^{-1} were on par with it. Among the B-lines ICSB 25001, ICSB 24001, ICSB 652, ICSB 323, and ICSB 724 were best performers for sugar yield ranging from 0.3 to 0.5 t ha^{-1} compared to the control ICSB 38 (0.1 t ha^{-1}).

Multilocation trials: A multilocation sweet sorghum hybrid trial (MSSHT) consisting of 10 hybrids (ICSA 38 × ICSV 700, ICSA 675 × ICSV 700, ICSA 702 × SSV 74, ICSA 724 × SSV 74 and ICSA 675 × SSV 74, JKSSH 02, JKSSH 03, PAC 8381, PAC 52093 and CSH 22SS), a multilocation sweet sorghum varietal trial (MSSVT) consisting of 10 varieties (SPV 422, NTJ 2, SP 4487-3, SP 4511-3, Urja, PA 27, RSSV 106, RSSV 138, RSSV 167 and SSV 84), a multiplication sweet sorghum maintainer lines trial (MSSBT) consisting of 5 B-lines(ICSB 324, ICSB 474, ICSB 479, ICSB 675 and ICSB 38) were evaluated in a three-replicated RBD design at 3 stages (flowering, dough and maturity) in three locations (ICRISAT, Patancheru, MPKV, Rahuri and TCL, Nanded) during 2009 rainy season.

Multilocation sweet sorghum hybrid trial (MSSHT): Days to 50% flowering data were recorded only at ICRISAT. Compared to CSH 22SS (90 days), all the hybrids flowered early (72 to 86 days). PAC 8381 was the earliest flowering hybrid (72 days) followed by ICSA 675 × ICSV 700 (73 days). For all other traits [stalk yield, cane yield, juice yield, Brix%, bagasse yield, sugar yield and grain yield], there were significant differences among the hybrids and also the locations influenced the traits. Also the stage of the crop had significant influence on these traits. At ICRISAT-Patancheru, the stalk yield decreased from flowering (52.3 t ha^{-1}) to maturity (44.0 t ha^{-1}), juice yield decreased from flowering (19.2 t ha^{-1}) to maturity (13.7 t ha^{-1}), Brix% increased from flowering (8.0) to maturity (17.6). But the sugar yield calculated as a product of Brix% and juice yield was low at flowering (1.6 t ha^{-1}) followed by maturity (2.4 t ha^{-1}). The sugar yield was highest at dough stage (2.6 t ha^{-1}). The hybrid ICSA 675 × SSV 74 was the highest sugar-yielding hybrid at all the three stages.

Multilocation sweet sorghum varietal trial (MSSVT): Compared to SSV 84 (90 days), all the varieties flowered early (68 to 88 days). RSSV 138 and RSSV 167 flowered in 68 days followed by Urja and SP 4511-3 (69 days). For all other traits [stalk yield, cane yield, juice yield, Brix%, bagasse yield, sugar yield and grain yield], there were significant differences among the varieties and also the locations influenced the traits. Also, the stage of the crop had significant influence on these traits.

At ICRISAT-Patancheru, the stalk yield (t ha^{-1}) decreased from flowering (54.5) to maturity (48.6), juice yield (t ha^{-1}) decreased from flowering (20.1) to maturity (13.7), Brix% increased from flowering (9.4) to maturity (18.1). But the sugar yield (t ha^{-1}) was low at flowering (1.94) followed by maturity (2.45). The sugar yield was highest at dough stage (2.53 t ha^{-1}). The variety PA 27 was the highest sugar yielding at all the three stages.

Multilocation sweet sorghum maintainer lines trial (MSSBT): Compared to ICSB 38 (71 days), all the B-lines flowered early (59 to 68 days). ICSB 474 flowered in 59 days followed by ICSB 479 (61 days). For all other traits [stalk yield, cane yield, juice yield, Brix%, bagasse yield, sugar yield and grain yield], there were significant differences among the varieties and the locations influenced the traits. Also, for most of the traits including sugar yield, stage of the crop had significant influence on these traits.

At ICRISAT, Patancheru, the stalk yield (t ha^{-1}) decreased from flowering (30.6) to maturity (28.9) and dough stages (28.7), juice yield (t ha^{-1}) decreased from flowering (9.1) to maturity (7.6), Brix% was highest at dough stage (13.3) followed by maturity (12.5) and flowering (9.0). But the sugar yield (t ha^{-1}) was low at flowering (0.9) followed by maturity (1.0). The sugar yield was highest at dough stage (1.1 t ha^{-1}). The B-line ICSB 479 was the highest sugar yielding at all the three stages.

Output target 2010: 5.2.1 SOPM Relationship between yield under terminal drought stay-green and root-related traits established in sorghum

Achievement of Output Target:
75%
One trial has been completed (2008-09) and a repeat trial is in progress, using the same entries as previous trial.

Participating countries:
Australia, India

Participating Partners:
NRCS, University of Queensland, Queensland Department of Plant Industry and Fisheries

Progress/Results:
We have tested over two different seasons a set of *germplasm* entries and introgression lines with 6 different stay-green QTL, in two different elite backgrounds. We have reported from Output target 2009 5.2.1 SOPM the possible contribution of difference in rooting to the maintenance of a stay-green phenotype. In the case of, we have clearly established that the maintenance of a stay-green phenotype was correlated to water absorption at the time genotypes can be discriminated well for stay-green. We have similar observations in sorghum. The quality of the data of water extraction (cv = 7.8% in a trial using 3 reps only) gives us confidence on the interpretation we can make after one year of trial.

Special Project Funding:
ACIAR

Output target 2010 5.2.3 SOPM Mapping and introgression of stay-green QTLs into elite parental lines, and assessment of their effects on hybrid performance completed

No report provided

Output target 2010 5.2.2 SOPM At least three pearl millet lines/parental lines with flowering- period heat tolerance at air temperatures exceeding 42^oC identified

Achievement of Output Target:
20%
Screening under natural field condition provided good results, while screening under controlled environment needs further fine-tuning. Two seed parental lines were tentatively identified with heat tolerance.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
A nursery involving about 100 entries comprising of hybrid parents and improved populations was evaluated at Aligarh (U P), Churu (Rajasthan), Bhabhar (Gujarat), Bhinmal (Rajasthan) and Patancheru in summer of 2009. Weather loggers were installed in the experimental fields to record climatic conditions. Based on the seed set of plants which faced temperatures of $\geq42^oC$ at flowering, following entries were found to be heat tolerant: Hybrids: 7701+, 9444, Euro-1, Euro-2, Nandi-5, Nandi-32 and Nandi-69; Designated seed parental lines: ICMB 92777 and ICMB 05666; and Populations: MC94 and ICTP 8202. Germplasm entries were evaluated as separate sets at different locations. In set I germplasm entries IP 19740, -19743, -19745, -19752, -19758, -19763, -19763, -19767, -19768, -19769, -19771, -19776 and IP-19778 had good seed set at Aligarh; while in set II , entries IP-19799, -19877, - 19882 and 19894 had good seed set at Bhabhar.

In a preliminary study under controlled environmental conditions (growth chambers), ICMB 92777 and 841B had shown variability for reproductive heat tolerance at temperatures of more than 42^oC. Selfed seed of 5 plants with high seed set (>80%) and 5 plants with low seed set (<10%), of both ICMB 92777 and 841B were screened twice under the same set of controlled environmental conditions in 2009 to investigate the repeatability of results. Plants with high seed set recorded low seed set and vice-versa in the repeat experiment. Large differences for seed set were also observed among self seed- derived plants of the same entry placed at different positions in the same chamber. This showed the ineffectiveness of screening protocol for heat tolerance under the present set of controlled environmental conditions in growth chamber.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2011 5.2.1 SOPM Relationship between yield under terminal drought and root- related traits established in pearl millet

Achievement of Output Target:
50%
We have carried out one trial and fully analyzed it. A repeat trial is planned for the forthcoming summer season that would complete the output target fully.

Participating Countries:
Ghana, India, UK

Participating Partners:
Institute of Grassland and Environmental Research (IGER), UK

Progress/Results:
We have used a lysimetric system and tested 8 entries introgressed with a terminal drought tolerance QTL. The lysemters were of 2.0 m length and 25 cm diameter and contained one pearl millet plant in each tube. The water stress treatment was applied by withdrawing irrigation at the time of booting (early stress ES) or flowering (late stress, LS), whereas a fully irrigated controlled (WW) was re-watered at approximately 80% field capacity every week. Plants of the ES and LS treatment received a last irrigation of 2 L per cylinder at booting and flowering stage, respectively (average across all genotypes). Until then, all treatments were fully irrigated. There were 10 replicated cylinders per treatment and genotypes. Under WW there were only small yield difference between lines. Under LS treatment, there was some clear yield advantage of PRLT-2/89-33 (donor of the drought tolerance QTL) and most NILs over H77/833-2 in the LS treatment but only an advantage of ICMR 01029 over H77/833-2 in the ES treatment. Best discrimination appeared to come from the LS treatment across saturation levels.

In the LS treatment, the total water extraction was similar in all genotypes, except ICMR 02044 that extracted about 1.2 L more water than H77/833-2. In that treatment, what varied most was the pattern of water extraction. NILs and PRLT-2/89-33 extracted less water soon after last irrigation but were capable of sustaining water extraction well into grain filling. In particular, water extraction was about 1L/week higher than in H77/833-2 in week 4 and 5 after booting. Water extraction in week 5 after booting was well correlated to final grain yield (R^2 = 0.45), and correlated even more significantly to tiller yield (R^2 = 0.79). These data showed that in the lines that were tested, a difference in the pattern of water use (less water taken up at the time of anthesis and more water left for absorption toward the end of grain filling) but no overall difference in the total volume of water taken up, was responsible for the differences in seed yield under terminal drought.

Special Project Funding:
Department for International Development (DFID-UK)-Biotechnology; Biological Sciences Research Council (BBSRC-UK)

Output target 2011 5.2.2 SOPM At least four parental lines of sorghum and six parental lines and populations of pearl millet with salinity tolerance developed/identified

Achievement of Output Target:
50%
One trial has been fully completed in 2008, where a number of parental lines have been screened for salinity tolerance. A repeat screening has to be done to confirm the earlier results.

Participating Countries:
India and CAC countries

Participating Partners:
International Centre for Bio-saline Agriculture (ICBA)

Progress/Results:
A repeat screening of 70 pearl millet entries, including R-lines, B-lines and breeding materials and populations were tested in saline and non-saline conditions, in outdoor conditions, using a buried pot system where salinity stress can be homogeneously applied. The trial carried out during the rainy season 2009 failed because of downy mildew in the control treatment and extreme severity of the saline treatment, due to a change in the soil lot. The trial will be repeated in 2010 using lower salt dose and ensuring that the soil is of good quality. No repeat of the sorghum material could be done this year due to space limitation in the screening facility.

Special Project Funding:
OFID-OPEC-funded Project on Salinity Tolerance

Output target 2012 5.2.1 SOPM Relationship between pearl millet parental lines and their hybrids for flowering-period heat tolerance at air temperatures exceeding 42 °C assessed

Achievement of Output Target:
No report as screening procedure under controlled environmental conditions is yet to be standardized for this study. Also, the lines validated for heat tolerance at target temperatures are yet to be identified.

Output 5.3: Germplasm and improved breeding lines with high and stable grain Fe and Zn content in sorghum and pearl millet hybrid parents made available to specific partners with associated knowledge and capacity building

Output target 2009 5.3.1 SOPM At least five sorghum germplasm hybrid parental lines with high Fe (>50 ppm) and Zn (>40 ppm) identified and made available to partners.

Achievement of Output Target:
100%
Eighteen collections with higher Fe contents (range 43-51 ppm) and 10 lines showed higher Zn contents (range 33-41 ppm) than the mean identified from evaluation for three years.

Participating Countries:
India and Mali

Participating Partners:
NARS (Public and Private sector) in India and Mali

Progress/Results:
Thirty six accessions from core collection of sorghum germplasm lines were evaluated for grain Fe and Zn contents in 2008 postrainy season and estimated for grain Fe and Zn contents at Waite Laboratory, Australia. They had an average Fe content of 42 ppm and average Zn content of 31 ppm with grain Fe content ranging from 30 to 51 ppm and Zn content from 21 to 41 ppm. Eighteen lines showed higher Fe contents (range 43-51 ppm) and 10 lines showed higher Zn contents (range 33-41 ppm) than the mean.

We also evaluated 250 ICRISAT-bred sorghum B-lines along with the control 296 B during the 2008 postrainy season for grain Fe and Zn contents at ICRISAT-Patancheru. The average grain Fe content of B-lines was 31 ppm and average Zn content was 17 ppm with grain Fe content ranging from 23 to 43 ppm and Zn contents from 10 to 28 ppm. The control 296B had 32 ppm Fe and 15 ppm Zn. A total of 63 B-lines showed higher grain Fe and Zn contents than 296B ranging from 33 to 43 ppm Fe and 13 to 28 ppm Zn.

Twenty commercial cultivars developed by Indian NARS in partnership with ICRISAT or by NARS alone (17 hybrids contributed by seven private sector seed companies and one hybrid by Marathwada Agricultural University, Parbhani and two varieties by Regional Agricultural Research Station, Acharya NG Ranga Agricultural University, Palem) along with two controls (CSH 16 and PVK 801) were evaluated in a RCBD trial with three replications in 2008 postrainy season for agronomic traits and grain Fe and Zn contents. The average Fe content of the cultivars was 48 ppm and average Zn content was 34 ppm with grain Fe content ranging from 37 to 57 ppm and grain Zn content from 26 to

46 ppm. The control CSH 16 developed by Indian national program had 50 ppm Fe and 34 ppm Zn. Five commercial hybrids showed higher Fe and Zn contents than CSH 16, ranging from 51 to 57 ppm for Fe and 34 to 46 ppm for Zn. The hybrids GK 4035 (Fe 57 ppm and Zn 46 ppm), Mahabeej 703 (Fe 53 ppm and Zn 36 ppm), Parbhani Sainath (Fe 52 ppm and Zn 34 ppm), Madhura SS hybrid (Fe 52 ppm and Zn 43 ppm), and Mahabeej 7 (Fe 52 ppm and Zn 33 ppm), were found promising for both Fe and Zn contents.

Advanced 10 BC$_1$s (B x B lustrous group) for high Fe and Zn B-line development in rainy season and selected 11 BC$_2$s for evaluation in postrainy season.

Special Project Funding:
HarvestPlus Challenge Program

Output target 2011 5.3.1 SOPM At least 10 germplasm accessions of sorghum from core collection with >60 ppm grain Fe and >40 ppm Zn content identified

Achievement of Output Target:
80%
With promising core collections germplasm lines identified for grain Fe and Zn contents, we have achieved 80% of the output target by now and validation of results is in progress.

Participating Countries:
India and Mali

Participating Partners:
NARS and Private sector in India and Mali

Progress/Results:
Fifty micronutrient-dense germplasm lines were evaluated in a separate trial during the 2008 postrainy season. The entries showed average Fe content of 45 ppm (SE$\pm$: 2.10) and average Zn content of 32 ppm (SE$\pm$: 1.58) with the Fe content ranging from 27 to 60 ppm and Zn content from 20 to 45 ppm. Twenty-one germplasm lines had higher grain Fe and Zn contents than the trial mean (Fe 45 ppm and Zn 32 ppm). Among them, IS 5514 (Fe 60 ppm and Zn 38 ppm), IS 4208 (Fe 56 ppm and Zn 36 ppm), IS 5426 (Fe 55 ppm and Zn 45 ppm) were found promising for grain Fe and Zn contents.

In the trial involving 118 micronutrient-dense freely threshable germplasm lines, the grain Fe content ranged from 23 to 59 ppm and Zn content from 16 to 41 ppm, with an average Fe content of 41 ppm (SE$\pm$: 2.82) and an average Zn content of 25 ppm (SE$\pm$: 1.63). Thirty-four lines showed higher grain Fe and Zn contents than the trial mean (Fe 41 ppm and Zn 25 ppm). Five accessions [IS 28376 (Fe 59 ppm and Zn 35 ppm), IS 12750 (Fe 59 ppm and Zn 38 ppm), IS 5229 (Fe 58 ppm and Zn 34 ppm), IS 5514 (Fe 60 ppm and Zn 38 ppm), IS 1222 (Fe 58 ppm and Zn 39 ppm) and IS 8728 (Fe 56 ppm and Zn 39 ppm)] were found promising for grain Fe and Zn contents.

The results from evaluation of 55 micronutrient-dense non-threshable germplasm lines showed Fe content ranging from 31 to 57 ppm and Zn contents from 19 to 39 ppm with an average Fe content of 39 ppm (SE$\pm$: 3.04) and average Zn content of 28 ppm (SE$\pm$: 2.00). Twenty-one lines showed higher grain Fe and Zn contents than the mean. The accessions IS 1563 (Fe 57 ppm and Zn 39 ppm), IS 12849 (Fe 46 ppm and Zn 30 ppm), IS 14108 (Fe 46 ppm and Zn 30 ppm), IS 8017 (Fe 60 ppm and Zn 38 ppm) and IS 12808 (Fe 43 ppm and Zn 32 ppm) were promising for grain Fe and Zn contents.

Special Project Funding:
HarvestPlus challenge program

Output target 2008/2009 5.3.1 SOPM Variability of Fe and Zn in commercial hybrids and core collection of the germplasm assessed in pearl millet

Achievement of Output Target:
90%
Results of the first set of commercial and pipeline hybrids were reported in 2008 Archival report. A trial of a second set that consisted of new hybrids as well as those having high Fe content in the first set was conducted at 10 locations. Grain samples produced at Patancheru were analyzed using NIRS method for Fe and Zn content. Grain samples from other five locations have been received. Full set of core collection was evaluated and grain samples were produced for Fe and Zn analysis.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl Millet Improvement Project; Pearl Millet Hybrid Parents Research Consortium seed companies

Progress/Results:
The first set of commercial and pipeline hybrids from 19 private seed companies evaluated earlier at Patancheru showed promising results with a large variation among the hybrids both for Fe content (47-85 ppm) and Zn content (36-70 ppm). Of these, 11 hybrids had >70 ppm Fe and > 50 ppm Zn contents. These hybrids along with the new ones were re-evaluated in 2009 in a second set of trial that consisted of 85 hybrids (13 from the public sector and 72 from 26 private seed companies). The trial was conducted at Patancheru and nine locations in India during the 2009 rainy season. Grain samples were produced at Patancheru and have also been received from five locations. Preliminary results based on Near-Infrared Reflectance Spectroscopy (NIRS) analysis of grain samples from Patancheru showed grain Fe ranging from 32 to 109 ppm and Zn ranging from 33 to 78 ppm. A private sector hybrid KH 302 had the highest Fe content (109 ppm), followed by an ICRISAT-bred hybrid ICMH 356 (109 ppm). Thirty hybrids had >70 ppm Fe and >50 ppm Zn, of which 13 hybrids had > 80 ppm Fe and > 60 ppm Zn. A commercial open-pollinated variety (ICTP 8203) used as a repeated high-iron control had 83-89 ppm Fe and 63-65 ppm Zn contents.

A subset of 166 accessions from core collection, initially identified for putative high-Fe content, based on a staining procedure, had been evaluated during 2007 to assess the grain Fe and Zn contents. However, grain samples used for staining had been produced in different years. Since the effect of environment on grain Fe/Zn content has been found to be quite substantial, the full set of the core collection (504 accessions) was evaluated during the 2009 postrainy season. Of these, only 470 accessions flowered for which grain samples were produced. These are yet to be analyzed for Fe and Zn contents.

Special project funding:
HarvestPlus Challenge Program

Output target 2010 5.3.2 SO Comprehensive information on genetics of grain Fe and Zn content in sorghum generated

Sorghum

Achievement of Output Target:
50%
Crosses were made using contrasting parents and the crosses along with parents are under evaluation for studying the gene action.

Participating Countries:
India and Mali

Participating Partners:
None

Progress/Results:
Crosses (2-3) will be made using contrasting parents and different generations (F_1, F_2, BC_1 and BC_2) will be developed to study the inheritance of grain Fe and Zn contents.

For studying the gene action, the progenies from crosses developed using contrasting parents comprising 28 F_1s and six parents for grain Fe content; 12 F_1s and four parents for grain Zn content; and 19 F_1 generations and five parents for studying grain Fe and Zn contents along with control (ICSR 40) are under evaluation in 2009 postrainy season for establishing the inheritance of grain Fe, grain Zn and grain Fe and Zn contents. The grain analysis for Fe and Zn contents will be carried out in 2010.

Special Project Funding:
HarvestPlus Challenge Program

Pearl Millet

Achievement of Output Target:
50%
Four sets of experiments have been underway. A diallel trial conducted earlier has been re-analyzed and the manuscript is under preparation. Two-season grain samples from a set I Line x Tester trial have been produced and one-season samples analyzed for Fe and Zn content. Grain samples from another set of Line x Tester trial have been produced for Fe and Zn analysis. Grain samples of S_1 and half-sib progenies from each of the two populations have also been produced for Fe and Zn analysis.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:
The Fe and Zn data from an earlier diallel experiment (part of a Ph.D. thesis) were re-analyzed. There was no significant difference in the results as compared to those arrived at from the previous analysis in that (i) both micronutrients are predominantly under additive genetic control, (ii) there were very high positive and significant correlations between the performance of lines *per se* and their general combining ability as well as hybrid performance, and (iii) no hybrid had Fe or Zn content higher than the better parents. A manuscript from this study is under preparation. In pursuance of genetic investigation, two sets of Line x Tester studies and a genetic variance study employing S_1 and half-sib progenies of two populations (a part of another Ph.D. thesis) is underway. Grain samples of the set I Line x Tester trial of 161 hybrids and their 26 parental lines were produced during the 2009 rainy and postrainy seasons. Analysis of the postrainy season grain samples showed that the Fe content in the male lines varied from 44 to 203 ppm, while in the female lines it varied from 55 to 135 ppm. The Zn content in the male lines varied from 44 to 139 ppm, while in the female lines it varied from 50 to 97 ppm. For both micronutrients, in general, there was no hybrid that exceeded the micronutrient levels of its better parent. Also, for both micronutrients, there was highly significant and positive correlation between the performance *per se* of the lines and their average hybrid performance (a measure of general combining ability).

We produced grain samples from another Line x Tester trial of 192 hybrids and their 28 parental lines. Grain samples were also produced from 60 S_1 and 60 half-sib progenies from two populations (AIMP 92901 and ICMR 312) which are yet to be analyzed for the Fe and Zn contents.

The results of the above studies are likely to have a bearing on the breeding approaches. One subject under investigation is to test the efficiency of single plant selection for these micronutrients. Seed samples from 40 random plants in each of the two populations (ICTP 8203 and JBV 3) were produced during the 2008 rainy season and their S_1 progenies were evaluated in 2009 postrainy season. Seed samples produced from the S_0 plants and S_1 progenies were analyzed for Fe and Zn content. Results showed highly significant and positive correlation between the grain samples from S_0 plants and S_1 progenies for both micronutrients and in both populations (r = 0.57 to 0.68) even though the grain samples came from two different seasons. This trial was repeated during the 2009 rainy season. A similar trial on other two populations (AIMP 92901 and ICMR 312) was also conducted during the 2009 rainy season and grain samples were produced.

Special project funding:
HarvestPlus Challenge Program

Output target 2011 5.3.2 PM At least six improved breeding lines of pearl millet with >90 ppm grain iron and >60 ppm Zn developed

Achievement of Output Target:
40%
More than 50 S_2 progenies from ICTP 8203 with >100 ppm Fe and many of these with > 60 ppm Zn content have been identified and will be further validated. Two other populations (CGP and GGP) in which high Fe/Zn progenies had been identified, will be re-evaluated.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
ICTP 8203 is a commercial variety that has shown large intra-population variability for both Fe and Zn contents. Starting with the evaluation of 300 S_1 progenies in 2008 postrainy season, and their progressively selective advancement, analysis of grain samples of 62 S_2 progenies produced from 2009 rainy season showed 50 of these having >100 ppm Fe and many of these having more than >60 ppm Zn contents. These will be further evaluated and subjected to inbreeding to develop improved breeding lines with high Fe and Zn contents.

Evaluation of 50 S_1 progenies each from two populations (CGP and GGP) during 2006 had identified several high Fe/Zn S_1 progenies. Re-sampling of these populations with 100 S_1 progenies each evaluated in 2007 also identified high Fe/Zn progenies, but their frequency and micronutrient levels were much less. Also, large differences were detected between the two replications. Thus, both sets of both populations will be re-evaluated to confirm the earlier results and to select those lines with high Fe/Zn contents for high-iron line development.

Special project funding:
HarvestPlus Challenge Program

Output target 2011 5.3.3 SOPM At least two high-yielding hybrids of pearl millet with >70 ppm Fe and > 50 ppm Zn developed.

Achievement of Output Target:
30%
More than 800 testcross hybrids grouped in four trials (2 each for the northern and peninsular India) were evaluated and 196 of these were selected based on agronomic performance of the hybrids and high-Fe levels of the pollinators for further evaluation.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl Millet Improvement Project; Pearl Millet Hybrid Parents Research Consortium seed companies

Progress/Results:
More than 800 testcross hybrids were generated during the 2009 postrainy season from crosses between 13 seed parents (A-lines or B-lines, depending on the seed availability) that had been earlier identified for high Fe content based on the ICP analysis, and restorer breeding lines for which there were indications of high Fe content based on a staining procedure. These hybrids were grouped into two testcross trials (Txt 1 and Txt 2, > 200 hybrids each) with probable adaption to peninsular India and were tested at more than three locations in peninsular India. Similarly, two trials (Txt 3 and Text 4, > 200 hybrids each) were constituted with probable adaptation to northern India, and were tested at more than three locations in northern India. All four trials were tested at Patancheru as well.

Based on the visually assessed field performance of the hybrids, and taking into account the NIRS-based Fe content of the pollinators, 196 hybrids were selected, of which 113 hybrids were from the two testcross trials conducted in peninsular India, and 83 were from the two testcross trials conducted in the northern India. One hundred-one hybrids had high selection scores at most of the locations and were considered of category 1, while 95 hybrids were selected as category 2 hybrids. These hybrids and their pollinators will be further evaluated for agronomic performance, DM resistance and Fe/Zn content.

Special project funding:
HarvestPlus Challenge Program

Output target 2012 5.3.1 SOPM Effectiveness of recurrent selection for grain Fe and Zn content in pearl millet demonstrated

Achievement of Output Target:
40%
Progeny evaluation for recurrent selection in ICTP 8203 continued. Recurrent selection in CGP and GGP was dropped. Instead, recurrent selection was initiated in two elite populations having adaptation to India, with the S_1 progeny evaluation in 2009 rainy season.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:

Fifty S_2 progenies out of 62 of an OPV (ICTP 8203) evaluated during the 2009 rainy season had >100 ppm Fe. These will be further evaluated for agronomic performance, including seed set, which will provide the basis to finally select 15-20 progenies for reconstituting the C_1 bulk. Based on the inconsistency in results, recurrent selection in CGP and GGP was dropped, which are basically breeding populations with no particular adaptation to the target regions in India. Instead, two other populations were selected for testing the efficiency of recurrent selection for Fe/Zn contents. These include an OPV (AIMP 92901) and a population pollinator of a topcross hybrid (ICMR 312), both released in India. Three hundred S_1 progenies of each of these two populations were evaluated and grain samples produced for Fe/Zn analysis. NIRS analysis showed large variability among the progenies both for the Fe content (46-138 ppm in AIMP 92910 and 30-131 in ICMR 312) and for Zn content (54-95 in AIMP 92901 and 41-95 in ICMR 312). High-Fe progenies from both populations will be identified to produce their C_1 cycle bulks.

Output target 2012 5.3.2 PM Improved versions of two OPVs with high Fe and Zn density developed

Achievement of Output Target:
40%
Improved versions of ICTP 8203 were evaluated along with the base population in a multi-locational trial. High-iron progenies are under further evaluation for developing additional versions. S_1 progenies of another commercial OPV (ICMV 221) were evaluated to develop its high Fe versions.

Participating Countries:
India

Participating Partners:
None

Progress/Results:

Three hundred S_1 progenies of the commercial OPV (ICTP 8203) had been evaluated during the postrainy season of 2008. Grain samples produced from these had been analyzed for Fe/Zn contents at ICRISAT and at the Waite laboratory. The S_1 progenies are expected to possess considerable within-line genetic variability. Since the seed for micronutrient analysis is normally produced from 4-5 selfed plants, the effect of sampling on the Fe/Zn contents is not well understood. Based on this assumption, remnant seed of the selected progenies as well as their seed produced from the progeny trials were used to develop improved versions. Thus, two improved versions were made by recombining 11 and 13 progenies having > 100 ppm Fe and >75ppm Zn content based on ICRISAT data. Similarly, two versions were made by recombining 10 and 18 progenies having more than 100 ppm Fe and > 75 ppm Zn based on the Waite laboratory data. Thus, four improved version for high Fe content along with the original C_0 bulk were evaluated at Patancheru and 13 other locations in Peninsular India for grain yield and agronomic traits. Grain yield and agronomic data were received from nine locations, including Patancheru. Grain samples were received from 7 locations, of which three locations have been analyzed for grain Fe/Zn content at the Waite laboratory. Based on the mean performance across the nine locations, the original ICTP 8203 bulk had 2874 kg ha^{-1} grain yield, while the improved versions had 3092-3166 kg ha^{-1} grain yield, outyielding the original bulk by 7.5-10%. The improved versions flowered 1-2 days earlier than the original population (48 days) and had had 14.5-15.3 g of the 1000-grain mass compared to 15.6 g for the original population. Based on the mean performance across the three locations for which the Fe/Zn data are available, improved versions had 94-103 ppm Fe content (7-17% more than the original bulk) and 63-69 ppm Zn (5-15-% more than the original population). Considering all attributes, two versions (one version each based on ICRISAT and Waite laboratory data) were the best with 8—10% higher grain yield, 16-17% higher Fe and 15% higher Zn content, as compared to the original population.

Four hundred S_1 progenies of ICMV 221 were evaluated during the 2009 postrainy season. NIRA analysis of grain samples showed large variation among the progenies both for Fe content (56-150 ppm) and Zn content (55-99 ppm), compared to 112-133 ppm Fe and 79-94 ppm Zn in the high-Fe variety ICTP 8203 used as a repeated control. Of these, 61 progenies had > 120 ppm Fe and > 80 ppm Zn content. About 50% of the progenies from the upper ranks will be identified for re-evaluation to identify those for developing a high Fe version of this variety.

Output target 2012 5.3.3 PM Two broad-based elite composites with >70 ppm Fe and >55 ppm Zn density developed

Achievement of Output Target:
40%
Designated B-lines with high Fe and Zn contents have been identified for random mating to constitute a high-Fe B-composite. Preliminary evaluation of designated R-lines and restorer breeding lines had been done and the lines showing high Fe content will be further evaluated to identify those for random mating and constituting a high-Fe R-composite.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl Millet Improvement Project; Pearl Millet Hybrid Parents Research Consortium seed companies

Progress/Results:

One hundred-thirty-five A/B pairs of pearl millet had been developed and designated up to 2008. These B-lines were evaluated during the 2009 postrainy season and grain samples produced were analyzed for Fe/Zn content using ICP procedure at the Waite laboratory. Results showed large variation among them both for Fe content (39-143 ppm) and zinc content (45-106 ppm). Thirty five B-lines > 100 ppm Fe were selected for recombination to initiate the formation of a high-Fe B-composite.

Sixteen IPC lines from ICRISAT Pollinator Collection earlier evaluated for high-Fe content were re-evaluated during the 2009 rainy season. Results showed these having 61-148 ppm Fe and 59-107 ppm zinc content. Ten of these lines had > 100 ppm Fe and >70 ppm zinc content. Twenty-seven restorer lines designated during 2006-2008 were also evaluated. The Fe content in these lines varied from 46 to 143 ppm and Zn content from 43 to 130 ppm. Four of these lines had 90-143 ppm Fe and three of these had 98-130 ppm Zn content. More than 450 advanced breeding lines from the restorer development program were screened for the Fe and Zn content using NIRS method. Results of this preliminary screening showed large variability among the lines both for the Fe content (29-143 ppm) and Zn content (47-95ppm). The high-Fe lines selected from these trials will be further evaluated to finally select those for the constitution of a high-Fe R-composite.

Special project funding:
HarvestPlus Challenge Program

Output 5.4: Sweet sorghum improved breeding lines with high and stable sugar and biomass made available to specific partners as hybrid parents with associated knowledge and capacity building

Output target 2009 5.4.1 SO More than 25 farmers trained in sweet sorghum ethanol value chain

Achievement of Output Target:
100%
Ten training programs were conducted for more than 200 lead farmers on sweet sorghum cultivars, cultivation aspects, use of planters, weeders and harvesters and operation of the decentralized crushing unit (DCU). Also training materials (2 flyers and one brochure) were developed.

Participating Countries:
India

Participating Partners:
NARS and Private sector

Progress/Results:
On-farm training (6) to farmers was conducted on various aspects of sweet sorghum cultivation in February 2009 in the cluster villages. Sweet sorghum field day conducted at Dharmapur village in Medak district in April 2009 was attended by >100 farmers. Soil health awareness meetings were organized in Ibrahimbad cluster May 28-29, 2009. Awareness meetings on shootfly were conducted in July 2009. Farmers field day conducted at Ibrahimbad village in Oct 2009 was attended by >70 farmers. Training on Operation and Management of DCU was conducted to educate rural youth (25 persons) at Ibrahimbad village in November, 2009.

Special Project Funding:
ICRISAT-Private Sector sorghum hybrid parents research consortium; IFAD Biofuels Project; NAIP-ICAR Sweet sorghum value chain development project

Output target 2010 5.4.1 SO First generation of improved hybrid parents available to consortium partners for testing with associated capacity development (associated with the SLP SWEP)

Achievement of output target:
70%
For postrainy season adaptation, we advanced 38 B-lines at BC_4 stage of their conversion into A-line which will be yield tested and used in hybrid development. In sweet sorghum, we have identified more than 60 A-/B-lines from ICRISAT-bred seed parents promising for sugar yield. They will be used extensively in development of new sweet sorghum hybrids. The advanced breeding lines will be test crossed and based on the maintainer reaction - lines will be included in conversion program to develop new male-sterile lines.

Participating Countries:
India, Philippines and Mali

Participating Partners:
NARS and Private sector

Progress/Results:
Dual-purpose B-line development

Rainy season adaptation: During the 2009 rainy season, 272 B-lines that include 149 B-lines at BC_5 stage (110 from BxB lustrous group and 39 from BxB non-lustrous group) 58 B-lines at BC_4 stage (10 from lustrous group, 2 from non-lustrous group, 11 from postrainy lustrous group, 32 from high yielding, grain mold tolerant group and 3 from high yielding non lustrous group), 22 B-lines at BC_2 stage (3 from lustrous group and 19 from high yielding group), and 43 B-lines at BC_1 stage (from B×B high yielding group) on A_1 cytoplasm were selected for high grain yield and rainy season adaptation. Further, 163 F_7s were selected for grain yield and agronomic desirability and testcrossed. To diversify the hybrid parents for rainy season adaptation, 251 F_6s, 26 F_3s and 2180 F_2s were selected based on grain yield and agronomic desirability. From the crosses made between grain mold resistant lines and high-yielding B-lines, 33 F_2s were selected, from the crosses made between shootfly resistant B-lines and high yielding sweet sorghum B-lines, 55 F_2s were selected, from the crosses made between high yielding B-lines, postrainy varieties, sweet sorghum germplasm lines and breeding lines, 120 F_2s were selected.

Postrainy season adaptation: During the 2008 postrainy season, 38 B-lines at BC_4 stage of their conversion into A-line were selected (with A_1 cytoplasm) based on the crosses involving high-yielding B-lines, postrainy B-lines, shootfly resistant B-lines and postrainy varieties for high yield and bold grain. These are being evaluated in a postrainy B-lines trial during the 2009 postrainy season.

From 2100 F_5 progenies evaluated, 1086 were selected and advanced to F_6 based on the grain yield, and grain size and luster during the 2008 postrainy season. These included 180 F_6 progenies derived from the crosses made between Gidda Maldandi and high yielding B-lines

(HYB) (these included crosses between Gidda Maldandi x 296B, Gidda Maldandi × HYB × HYB, Gidda Maldandi × postrainy B-lines, Gidda Maldandi × HYB × M 35-1 bulk, Gidda Maldandi × HYB × postrainy variety), 277 F_6 progenies derived from the crosses made between postrainy landrace varieties and HYB, 61 F_6 progenies derived from the crosses made between postrainy varieties and high yielding B-lines, 155 F_6s derived from the crosses made between M 35-1 and HYB, and 413 F_6s derived from the crosses made between high yielding B-lines.

From the crosses between lustrous germplasm lines, HYB and postrainy varieties, 322 selected progenies were advanced to F_5 based on grain yield, grain size and grain luster from 487 F_4 progenies evaluated during the 2008 postrainy season.

A total of 177 F_4 progenies were developed based on grain boldness and luster and grain yield from 789 F_3 progenies evaluated during the 2008 postrainy season. These included 144 F_4 progenies derived from postrainy season varieties × HYB and 33 F_4 progenies derived from landrace varieties × postrainy B-lines and postrainy R-lines.

Dual-purpose R-line development

Rainy season adaptation: From HYB × HYB, M 35-1 bulk × HYB, Gidda Maldandi × HYB, high yielding germplasm lines × HYB crosses, 141 F_7s were developed based on grain yield and rainy season adaptation from 978 F_6s evaluated. From the crosses involving high yielding R-lines and varieties, 119 F_6s were produced from 352 F_5s evaluated, 36 F_6s from 401 F_5s evaluated (with sweet sorghum and grain Fe and Zn traits introgressed), 52 F_5s from 301 F_4s evaluated, and 20 F_4s from 129 F_3s evaluated. For various traits, F_1s were advanced to F_2s that included 30 F_2s derived from the crosses between shootfly resistant lines from germplasm and shootfly resistant varieties, 34 F_2s derived from three-way crosses made between high yielding lines, and 54 F_2s derived from the crosses made between postrainy adaptation F_1s and Gidda Maldandi, Dagidi solapur (1, 2, 3), SPV 1411, SPV 1359, Barshizoot.

Postrainy season adaptation: From the crosses made between postrainy R-lines, 53 F_4s were produced from 18 F_3s evaluated with selection for bold grain, luster and grain yield. From postrainy variety × variety and from postrainy variety × HYB crosses 166 F_5s were produced from 157 F_4s evaluated. From 725 F_5s evaluated during the 2008 postrainy season, 502 F_6s were produced based on grain yield, bold grain and postrainy season adaptation. These included 326 F_6s selected from postrainy RxR crosses, 6 F_6s from postrainy variety × variety crosses, 19 F_6s from Gidda Maldandi x postrainy variety crosses and 151 F_6s from postrainy germplasm lines × postrainy varieties crosses. The selected F_4s, F_5s and F_6s are being evaluated during the 2009 postrainy season.

Sweet sorghum

Rainy season adaptation

A total of 1373 F_3s from 299 F_2s derived from crosses between sweet sorghum improved R-lines, 637 F_4s from 222 F_3s, 1355 F_6s from 573 F_5s and 234 F_5s from144 F_4s were selected for high Brix% (above 17%) and high biomass during the 2009 rainy season.

B-lines development: From the evaluation of a total of 307 F_4s derived from the crosses involving high yielding B-lines, sweet sorghum B-lines and sweet sorghum varieties, 205 F_5s were produced during the 2008 postrainy season based on stem juiciness, Brix%, high biomass and good grain yield for sweet sorghum B-line development. A total of 5 F_4s from 24 F_3s were obtained during the 2008 postrainy season from the crosses between sweet sorghum varieties and sweet sorghum germplasm lines with selection for stalk juiciness, Brix% and high biomass. A total of 14 F_3s produced from crosses made between high yielding B-lines, high yielding R-lines and sweet sorghum improved R-lines are being advanced during the 2009 postrainy season.

Postrainy season adaptation

From the evaluation of a total of 1234 F_4s derived from the crosses made involving sweet sorghum varieties and sweet sorghum germplasm lines, 906 F_5s were produced for stalk juiciness and high biomass during the 2008 postrainy season. A total of 418 F_4s (from 333 F_3s) and 396 F_3s (from 212 F_2s) were produced for stalk juiciness, Brix% and high biomass during the 2008 postrainy season. From the crosses made between sweet sorghum landraces, sweet sorghum varieties, East and West African landraces, high biomass lines, 296 F_2s were harvested with selection for high Brix% (18 to 20) and are being advanced during the 2009 postrainy season.

From a total of 212 F_3s derived from the crosses involving new sweet sorghum varieties and sweet sorghum germplasm lines, 482 F_4s were produced for Brix% (18-20) and high biomass during the 2008 postrainy season.

Special Project Funding:
ICRISAT-Private sector sorghum hybrid parents' research consortium; IFAD Biofuels Project

Output target 2011 5.4.1 SO More than 25 scientists trained in sweet sorghum hybrid parents development through an international training course

Achievement of Output Target:
100%
One bulletin each on Sweet sorghum and establishment and maintenance of decentralized crushing cum syrup making unit (DCU) published.

Participating Countries:
Open to all countries

Participating Partners:
NARS and Private sector
Progress and Results:
Eight researchers were trained on different aspects of sorghum breeding
- A Kola Lavakusa Rao from India worked as an intern on sweet sorghum evaluation from 18 May to 17 Sep 2009.
- Remolacia Mario Imperio from the Philippines was trained on seed multiplication and evaluation of sweet sorghum cultivars from 23 March to 22 April 2009.

- Richard Dar Dela Cruz from the Philippines was trained on seed multiplication and evaluation of sweet sorghum cultivars from 23 March to 22 April 2009.
- Valentin Corpuz Godoy from the Philippines was trained on Sweet Sorghum crop production and diseases, and Post harvest operations from 17 September to 15 October 2009.
- Odilon Villanueva Caraan from the Philippines was trained on Sweet Sorghum crop production and diseases, and Post harvest operations from 17 September to 15 October 2009.
- Lee Yong Hwa from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009
- Moon Youn Ho from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009
- Jong Rae from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009

Special Project Funding:
ICRISAT-Private Sector Sorghum Hybrid Parents Research Consortium

Output targets 2012 5.4.2 SO Toxigenic Fusarium species associated with sorghum grain mold characterized and genetic resistance to these in sorghum genotypes identified

Achievement of Output Target:
50%
Fusarium species and their *toxigenic* strains involved in the GM complex have been identified and genetic resistance to these will be identified during the next 2 years. It would be then desirable to understand the genetics of resistance to *Fusarium* strains and their relationships with other mold pathogen, such as *Curvularia* and *Alternaria.*

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Species of Fusarium are a major component of the fungal complex that cause grain mold in sorghum. Some of the species of Fusarium produce mycotoxins, such as fumonisins and trichothecenes that are hazardous to human and cattle health. It is, therefore, important to characterize the Fusarium isolates from grain mold for their mycotoxin-producing potential and determine their speciation. Finally, resistance to the toxigenic Fusaria should be identified in sorghum lines for utilization in resistance breeding program.

Characterization of Fusarium species associated with sorghum grain mold using DNA markers: A total of 672 isolates of *Fusarium* were collected from naturally molded sorghum grains from five locations (Akola, Parbhani, Patancheru, Palem and Surat) in India during 2003-05. Sixty-three representative isolates were selected to study genetic relatedness/diversity through amplified fragment length polymorphism (AFLP) and *α-Elongation factor* (EF1) sequence-based identification. Five EcoR1-Mse1 AFLP primer combinations (Etg + Mcag, Eaa + Mctt, Eac + Mcag, Etc + Mctt and Etg + Mcag), were examined in the 63 isolates. AFLP profiles were used to construct a binary matrix and the data were then analyzed using Numerical Taxonomy System Version 2.2 (NTSYSpc). DNA sequence variation was assessed by sequencing part of *α*-EF1 with gene-specific primer pair using BigDye Terminator cycle sequencing kit on ABI3130XL (Applied Biosystems, California, USA). The sequences were aligned through CLUSTAL W. The dissimilarity index was calculated from the aligned sequences of different isolates using 'Simple matching' option in DARwin and a weighted neighbor joining tree was constructed. Sequences of the EF1-PCR fragments were searched against those in the NCBI database using BLAST for species identification.

High level of polymorphism was observed among isolates following selective amplification with 5 AFLP primer combinations. The dendrogram generated from the AFLP data revealed genetic diversity among the isolates, clustering them into different groups. Five major groups were identified and the isolates of the same species were clustered together. The sequences of EF-1α gene from each of the 63 *Fusarium* isolates were compared to those from various known species of *Fusarium* in the NCBI database. Five species of *Fusarium* – *F. proliferatum, F. thapsinum, F. equiseti, F. andiyazi* and *F. sacchari* were identified based on sequence similarity. Neighbor joining tree constructed using *α-Elongation factor* gene sequence of test isolates clustered the isolates of the same species in the distinct groups. *Fusarium. thapsinum* was identified as predominant species in *Fusarium* – grain mold complex in India.

Estimate fumonisins-producing potential of *Fusarium* cultures of different species using ELISA/HPLC to identify toxigenic *Fusarium* isolates: The single-spore cultures of 63 selected isolates of *Fusarium* were grown on sterilized sorghum grains for 4 weeks at 25 ºC and the colonized sorghum grain samples were tested for fumonisins through ELISA. Strains of *F. proliferatum* (10 out of 12 isolates) were identified as highly toxigenic for fumonisin production followed by *F. andiyazi*. Strains of *F. thapsinum, F. equiseti,* and *F. sacchari* appeared non-toxigenic, however, one isolate of *F. thapsinum* (F88) produced considerable amount of fumonisins. The test isolates are being analyzed through HPLC for confirmation of these results to identify highly toxigenic strains of *Fusarium* for the greenhouse screening of sorghum lines.

Inheritance of resistance to *Curvularia lunata* in sorghum: To study inheritance of resistance against *Curvularia lunata,* a major pathogen in the sorghum grain mold complex F_1, F_2, BC_1F_1s and parents of the cross Bulk Y-P1 × ICSB 377-P1 were screened in the greenhouse. Panicles were inoculated at >80% anthesis stage with conidial suspensions (1×10^6 spores mL^{-1}) of *C. lunata* and exposed to wetness for 48 h after inoculation. High humidity was again provided from the soft dough stage to physiological maturity (PM) by overhead foggers to facilitate disease development. Grain mold was recorded at physiological maturity using a progressive 1 to 9 scale.

Mean grain mold scores for the resistant parent (ICSB377) and susceptible parent (Bulk-Y) were 2.0 and 8.0, respectively. Of the 187 F_2 plants, 139 were resistant (score ≤3.0) and 48 susceptible (score >3.0). The χ^2 test for a single dominant gene ratio (χ^2=0.04, *p*=0.80), revealed a perfect fit for this population segregating in a 3 (resistant):1 (susceptible) ratio. This indicated the role of a single major gene in governing resistance to *C. lunata*. These results were further confirmed in backcross progenies of F_1s with both the parents. As expected the backcross progenies of F_1s with resistant parent were all resistant, and those with susceptible parent segregated in 1 (resistant): (1

susceptible) ratio. Similar results were obtained during 2008 which confirms that resistance to *C. lunata* in ICSB 377-P1 is governed by single dominant gene.

Special Project Funding:
Suri Sehgal Foundation Endowment Fund

Output targets 2012 5.4.3 SO Greenhouse screening technique for sorghum rust standardized and new sources of rust resistance identified

Work to be initiated in 2010

<div align="right">RP Thakur</div>

Output 5A: Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite backgrounds, for specific target markets, production environments and research application made available biennially (from 2008) to defined partners with associated knowledge and capacity building in the Asian SAT

Sorghum

Output target 5A.1 More than 35 parental lines of potential sorghum hybrids with high grain yield, and improved agronomic traits and biotic resistance developed (2007-2009)

Activity 5A.1.1 Develop and characterize a diverse range of improved parental lines

Milestone 5A.1.1.1 Ten male-sterile lines and five restorer lines with high yield and large grain developed (BVSR, 2007)

Achievement of output target:
100%
Based on the evaluation of recently developed grain sorghum hybrid parents (A/B and R-lines), 25 B-lines and 10 R-lines with high grain yields and agronomic desirability were identified.

Participating Countries:
India

Participating Partners:
Nil

Progress/Results:

A. Dual-purpose B-line development
One hundred ninety B-lines that had earlier been converted into male-sterile lines were evaluated for their performance and characterized for agronomic traits in three-replication yield trials in RCBD (Randomized Complete Block Design) during both the 2008 postrainy and 2009 rainy seasons. The results are given below.

Postrainy season:

Elite A_1-based B-lines trial (EBTA$_1$): Eight maintainers of A_1 cytoplasm selected from the advanced B-lines trial during the 2008 rainy season were evaluated in EBTA$_1$ during the 2008 postrainy season along with the controls 296B and ICSB 52. All the B-lines with grain yield ranging from 3.7 to 4.9 t ha^{-1} were comparable to both the controls, 296B (3.9 t ha^{-1}) and ICSB 52 (4.9 t ha^{-1}) for grain yield. The grain size of these lines ranged from 2.2 to 3.3 g 100^{-1} grains (296B: 3.0 g 100^{-1} grains, ICSB 52: 4.1 g 100^{-1} grains), grain luster score (taken on a scale where 1=most lustrous, and 3=least lustrous) was 3.0 (296B: 3.0, ICSB 52: 3.0), days to flowering ranged from 77 to 83 days (296B: 85 days, ICSB 52: 74 days) and plant height ranged from 1.3 to 1.9 m (296B: 1.2 m, ICSB 52:1.6 m). These eight A/B pairs will be designated with ICSA/B numbers.

Elite A_2-based B-lines trial (EBTA$_2$): Thirteen maintainers of A_2 cytoplasm selected from the advanced B-lines trial during the 2008 rainy season were evaluated in EBTA$_2$ during the 2008 postrainy season along with the controls 296B and ICSB 52. Eight B-lines with the grain yield ranging from 5.6 to 6.5 t ha^{-1} were significantly superior to postrainy B-line control, ICSB 52 (4.6 t ha^{-1}) by 21.7 to 41.3%. The grain size of these lines ranged from 2.2 to 3.1 g 100^{-1} grains (296B: 2.5 g 100^{-1} grains, ICSB 52: 4.1 g 100^{-1} grains), grain luster score ranged from 2.0 to 3.0 (296B: 3.0, ICSB 52: 3.0), days to flowering ranged from 75 to 87 days (296B: 85 days, ICSB 52: 75 days) and the plant height ranged from 1.3 to 1.9 m (296B: 1.2 m, ICSB 52:1.6 m). These eight A/B pairs will be designated with ICSA/B numbers.

Advanced B-lines trial (ABT): Thirteen maintainers of A_1 cytoplasm selected from the preliminary B-lines trial during the 2008 rainy season were evaluated in ABT along with the controls 296B and ICSB 52 during the 2008 postrainy season. One B-line (6.0 t ha^{-1}) was significantly superior to both the controls, 296B (3.9 t ha^{-1}) and ICSB 52 (4.3 t ha^{-1}) for grain yield. Eleven B-lines (4.4 to 5.4 t ha^{-1}) were comparable and numerically superior to both the controls for grain yield by 2.3 to 25.6%. The grain size of the 12 B-lines ranged from 2.6 to 3.2 g 100^{-1} grains (296B: 2.8 g 100^{-1} grains, ICSB 52: 4.2 g 100^{-1} grains), grain luster score from 2.0 to 3.0 (296B: 3.0, ICSB 52: 3.0), days to flowering from 77 to 88 days (296B: 84 days, ICSB 52: 74 days), and the plant height from 1.4 to 1.9 m (296B: 1.3 m, ICSB 52:1.5 m).

Preliminary A_1-based B-lines trial (PBTA$_1$): Nineteen maintainers of A_1 cytoplasm with counterpart male-sterile lines in BC$_6$ generation were evaluated in PBTA$_1$ during the 2008 postrainy season along with the controls 296B and ICSB 52. Fourteen B-lines with grain yield ranging from 4.4 to 6.1 t ha^{-1} were comparable to the best performing control ICSB 52 (5.4 t ha^{-1}), while twelve B-lines were significantly superior to 296B (3. 5 t ha^{-1}) by 37 to 76%. The grain size in these 12 B-lines ranged from 2.1 to 2.8 g 100^{-1} grains (296B: 3.1 g 100^{-1} grains, ICSB 52: 3.6 g 100^{-1} grains), grain luster score from 2.0 to 2.3 (296B: 3.0, ICSB 52: 2.7), days to flowering from 76 to 90 days (296B: 84 days, ICSB 52: 74 days) and plant height from 1.2 to 1.5 m (296B: 1.3 m, ICSB 52:1.6 m).

Preliminary A$_2$-based B-lines trial (PBTA$_2$): Twenty-one maintainers of A$_2$ cytoplasm with counterpart male-sterile lines in BC$_6$ generation were evaluated in PBTA$_2$ during the 2008 postrainy season along with the controls 296B and ICSB 52. The B-line SP 93089 (6.09 t ha^{-1}) was significantly superior to the best performing control ICSB 52 (4.32 t ha^{-1}) for grain yield. Fifteen B-lines with grain yield ranging from 4.42 to 5.52 t ha^{-1} were comparable to ICSB 52 and numerically superior by 2 to 28%, while nineteen B-lines with a grain yield ranging from 3.86 to 6.09 t ha^{-1} were significantly superior to the control, 296B (2.43 t ha^{-1}) by 59 to 151%. The grain size in these 19 B-lines ranged from 2.6 to 3.3 g 100^{-1} grains (296B: 2.9 g 100^{-1} grains, ICSB 52: 4.0 g 100^{-1} grains), grain luster score from 2.3 to 3.0 (296B: 3.0, ICSB 52: 3.0), days to flowering from 74 to 79 days (296B: 86 days, ICSB 52: 74 days) and plant height from 1.4 to 1.8 m (296B: 1.2 m, ICSB 52:1.5 m).

Rainy season:

Advanced A$_1$B-lines trial (ABTA$_1$): Thirteen maintainers of A$_1$ cytoplasm selected from the PBTA$_1$ and ABT during the 2008 postrainy season were evaluated in ABTA$_1$ along with the controls 296B, ICSB 52, IS 18551 and Swarna during the 2009 rainy season. Three B-lines with grain yield of 3.1 to 3.4 t ha^{-1} were significantly superior over the best control, 296B (2.5 t ha^{-1}) by 24 to 36% for grain yield. These three lines flowered in 72 to 74 days (296B: 67 days, ICSB 52: 66 days) and had a plant height of 1.4 to 1.5 m (296B: 1.2 m, ICSB 52: 1.5 m). The shootfly dead hearts% of these lines ranged from 31 to 40 (IS 18551: 19, Swarna: 53). One B-line with comparable grain yield (2.4 t ha^{-1}) to both the controls was tolerant to shootfly (31% dead hearts).

Advanced A$_2$B-lines trial (ABTA$_2$): Fourteen maintainers of A$_2$ cytoplasm selected from the PBTA$_2$ and ABT during the 2008 postrainy season were evaluated in ABTA$_2$ along with the controls 296B, ICSB 52, IS 18551 and Swarna during the 2009 rainy season. Five B-lines with grain yield of 3.0 to 4.1 t ha^{-1} were significantly superior to the best control, 296B (2.2 t ha^{-1}) by 36 to 86% for grain yield. These B-lines flowered in 63 to 66 days (296B: 66 days, ICSB 52: 66 days) and had a plant height of 1.4 to 1.7 m (296B: 1.3 m, ICSB 52: 1.5 m). The shootfly dead hearts% of these lines ranged from 41 to 82 (IS 18551: 14, Swarna: 80).

Preliminary A$_1$B-lines trial (PBTA$_1$): Fifty-five maintainers of A$_1$ cytoplasm with counterpart male-sterile lines in BC$_6$ generation were evaluated in PBTA$_1$ during the 2009 rainy season along with the controls 296B and ICSB 52. Thirty-two B-lines with a grain yield of 2.2 to 4.0 t ha^{-1} were significantly superior over the controls, 296B (by 38 to 150%) and ICSB 52 (by 144 to 344%) for grain yield. These B-lines flowered in 61 to 75 days (296B: 67 days, ICSB 52: 67 days) and had a plant height of 1.3 to 2.0 m (296B: 1.3 m, ICSB 52: 1.6 m). The B-line, SP 27841 had the highest grain yield of 4.0 t ha^{-1}, flowered in 68 days, and had a plant height of 1.5 m and Panicle grain mold rating (PGMR) (taken on a scale 1 to 9 where 1= <10% and 9= >90% mold infected grains) score of 2.7. Among these, 12 B-lines had a PGMR score below 3.0 (296B: 5.0, ICSB 52: 5.0).

Preliminary A$_2$B-lines trial (PBTA$_2$): Thirty-four maintainers of A$_2$ cytoplasm with counterpart male-sterile lines in BC$_6$ generation were evaluated in PBTA$_2$ during the 2009 rainy season along with the controls 296B and ICSB 52. Five B-lines with grain yield of 2.1 to 2.3 t ha^{-1} were significantly superior over the controls, 296B (by 31 to 44%) and ICSB 52 (by 110 to 130%) for grain yield. These B-lines flowered in 67 to 71 days (296B: 66 days, ICSB 52: 66 days), had a plant height of 1.4 to 1.8 m (296B: 1.2 m, ICSB 52: 1.5 m) and the PGMR score of 3.0 to 4.3 (296B: 4.3, ICSB 52: 4.7).

B. Dual-purpose R-line development
From the hybrid parent development program for rainy season adaptation, promising F$_5$ progenies with restorer reaction on A$_1$ and/or A$_2$ CMS systems were evaluated in three-replicated yield trials (Preliminary R-lines trial (PRT), Advanced R-lines trial (ART) and Elite R-lines trial (ERT) in RCBD during both rainy and postrainy seasons. The results are as follows.

Postrainy season:

Elite R-lines trial (ERT): Ten R-lines selected from the advanced R-lines trial evaluated during the 2008 rainy season were evaluated in ERT during the 2008 postrainy season along with the controls RS 29 and SPV 1616. Five R-lines with grain yield ranging from 5.1 to 5.9 t ha^{-1} were comparable to RS 29 (5.9 t ha^{-1}). The grain size in these lines ranged from 2.0 to 3.4 g 100^{-1} grains (RS 29: 2.1 g 100^{-1} grains), grain luster score from 2.0 to 3.0 (RS 29: 2.7), days to flowering ranged from 77 to 89 days (RS 29: 87 days) and the plant height from 1.5 to 1.9 m (RS 29: 1.8 m). These five lines will be designated with ICSR numbers.

Advanced R-lines trial (ART): Six R-lines selected from the preliminary R-lines trial evaluated during the 2008 rainy season were evaluated in ART during the 2008 postrainy season along with the controls RS 29 and SPV 1616. All the R-lines with grain yield ranging from 4.41 to 6.28 t ha^{-1} were comparable to SPV 1616 (6.06 t ha^{-1}), while two R-lines were comparable to RS 29 (7.07 t ha^{-1}). The grain size in these lines ranged from 2.51 to 3.98 g 100^{-1} grains (SPV 1616: 2.92 g 100^{-1} grains), grain luster score from 2.0 to 3.0 (SPV 1616: 3.0), days to flowering from 77 to 87 days (SPV 1616: 75 days) and the plant height from 1.6 to 1.9 m (SPV 1616: 2.1 m).

Preliminary R-lines trial (PRT): Eighty three advanced progenies identified as restorers during the 2008 rainy season were evaluated in PRT during the 2008 postrainy season along with the controls RS 29 and SPV 1616. Three R-lines (6.0 to 6.4 t ha^{-1}) were numerically superior to the control, RS 29 (5.94 t ha^{-1}) for grain yield by 1 to 8%. A total of 27 R-lines (4.92 to 6.40 t ha^{-1}) were numerically superior to the control SPV 1616 (4.91 t ha^{-1}) by 0.2 to 30% and comparable to RS 29. Among the 27 R-lines, grain size ranged from 3.16 to 3.52 g 100^{-1} grains (RS 29: 2.12 g 100^{-1} grains, SPV 1616: 3.11 g 100^{-1} grains), grain luster score from 2.0 to 3.0 (RS 29: 2.3, SPV 1616: 3.0), days to flowering from 75 to 89 days (RS 29: 87 days, SPV 1616: 75 days) and plant height from 1.2 to 2.0 m (RS 29: 1.8 m, SPV 1616: 2.1 m).

Dual-purpose R-lines trial (DRT): With a view to develop R-lines suitable for both grain and fodder, several crosses were made involving grain sorghum R-lines, sweet sorghum R-lines, brown midrib sources and forage varieties. The selected progenies with restorer reaction were evaluated in preliminary trials and the selected seven restorers were evaluated in DRT during the 2008 postrainy season along with the controls, RS 29 and NTJ 2. Compared to the dual-purpose variety NTJ 2 (4.27 t ha^{-1}), six R-lines (4.30 to 5.28 t ha^{-1}) were numerically superior for grain yield by 0.7 to 24%. They flowered in 74 to 84 days (NTJ 2: 75 days) and had a plant height of 1.8 to 2.8 m (NTJ 2: 2.1 m).

Rainy season:
Advanced cream grain colored R-lines trial (ACRT): Eighteen cream grain colored R-lines selected from PRT, ART, ERT, DRT trials conducted during the 2008 postrainy season were evaluated in ACRT during the 2009 rainy season along with the controls RS 29, ICSR 89058, M 35-1 and ICSB 52. Compared to the best performing control RS 29 (2.7 t ha^{-1}), one R-line (3.5 t ha^{-1}) was significantly superior for grain yield by 30% and 11 R-lines with the grain yield ranging from 2.2 to 3.0 t ha^{-1} were comparable to it. These 12 R-lines flowered

from 67 to 81 days (RS 29: 72 days) and had a plant height of 1.5 to 2.7 m (RS 29: 1.9 m). The PGMR score in these lines ranged from 2.3 to 4.3 (RS 29: 3.0).

Advanced white grain colored R-lines trial (AWRT): Eleven white grain colored R-lines selected from PRT, ART, ERT, DRT trials conducted during the 2008 postrainy season were evaluated in AWRT during the 2009 rainy season along with the controls RS 29, ICSR 89058, M 35-1 and ICSB 52. Compared to the best performing control RS 29 (2.3 t ha^{-1}), four R-lines with the grain yield ranging from 2.0 to 2.6 t ha^{-1} were comparable and three were numerically superior by 4 to 13%. These R-lines flowered from 71 to 81 days (RS 29: 82 days) and had a plant height of 1.3 to 1.6 m (RS 29: 1.7 m). The PGMR score ranged from 2.3 to 3.7 (RS 29: 2.0).

Preliminary cream grain colored R-lines trial (PCRT): Seventy-six cream grain colored R-lines selected from advanced progenies identified as restorers during the 2008 postrainy season were evaluated in PCRT during the 2009 rainy season along with the controls RS 29, ICSR 89058, M 35-1 and ICSB 52. Compared to the best performing control RS 29 (2.3 t ha^{-1}), two R-lines, SP 25250-1 (3.1 t ha^{-1}) and SP 25291-2 (3.0 t ha^{-1}) were significantly superior for grain yield and 43 R-lines with the grain yield ranging from 1.9 to 2.5 t ha^{-1} were comparable to it. These 45 R-lines flowered from 65 to 86 days (RS 29: 71 days) and had a plant height of 1.3 to 2.2 m (RS 29: 1.7 m). The PGMR score ranged from 2.0 to 4.3 (RS 29: 3.0). The R-line, SP 25272-2 was most tolerant to grain mold with a score of 2.0 (grain yield: 1.9 t ha^{-1}, days to 50% flowering: 71 days and plant height: 1.8 m).

Preliminary white grain colored R-lines trial (PWRT): Seventy-three white grain colored R-lines selected from advanced progenies identified as restorers during the 2008 postrainy season were evaluated in PWRT during the 2009 rainy season along with the controls RS 29, ICSR 89058, M 35-1 and ICSB 52. Compared to the R-line control ICSR 89058 (2.1 t ha^{-1}), fourteen R-lines with the grain yield ranging from 2.6 to 3.4 t ha^{-1} were significantly superior by 24 to 62%. These R-lines flowered from 68 to 76 days (ICSR 89058: 68 days) and had a plant height of 1.4 to 2.1 m (ICSR 89058: 1.7 m). The PGMR score ranged from 2.0 to 3.7 (ICSR 89058: 3.3). The R-lines, SP 31791-1 and SP 25273-2 were most tolerant to grain mold with a score of 2.0 (grain yield: 3.0 t ha^{-1}, days to 50% flowering: 69 and 71 days and plant height: 1.7 m).

Preliminary brown-midrib R-lines trial: Twenty six newly developed restorers of the A$_1$ CMS system introgressed with brown midrib (*bmr*) trait utilizing *bmr* sources IS 21887 (*bmr* 1), IS 21888 (*bmr* 3) and IS 21890 (*bmr* 7) were evaluated along with their parental *bmr* sources i.e. *bmr* 1, *bmr* 3 and *bmr* 7 as *bmr* controls and a high grain-yielding white midrib variety RS 29 as non-*bmr* control during the 2008 postrainy season. Twenty five R-lines recorded a *bmr* score 1 (taken on a 1–3 scale, where 1 = brown, 2 = green and 3 = white) and 22 of these lines recorded a lodging score <2.0 (taken on a 1-5 scale, where 1= <10% lodging and 5= 100% lodging). Grain yield in these lines ranged from 2.3 to 5.2 t ha^{-1} (*bmr* controls: 2.3 t ha^{-1}; RS 29: 6.0 t ha^{-1}), days to 50% flowering from 74 to 85 days (RS 29: 84 days) and plant height from 1.0 to 1.9 m (RS 29: 1.7 m). Nine taller lines (>1.6 m) with *bmr* score 1 and high grain yield (> 4.0 t ha^{-1}) were identified for further evaluation.

Advanced brown-midrib R-lines trial: Ten restorers of the A$_1$ CMS system introgressed with IS 21887 (*bmr* 1) and IS 21890 (*bmr* 7), selected from preliminary brown-midrib R-lines trial during the 2007 rainy season along with two high grain-yielding white midrib controls ICSR 89058 and RS 29 were evaluated during the 2008 postrainy season. Nine R-lines recorded a *bmr* score 1. Among these, grain yield ranged from 2.3 to 4.0 t ha^{-1} (*bmr* control: 1.4 t ha^{-1}; RS 29: 5.8 t ha^{-1}; ICSR 89058: 4.0 t ha^{-1}) and plant height from 1.5 to 2.0 m (RS 29: 1.8 m; ICSR 89058: 1.7 m). *In vitro* digestibility of these lines ranged from 50.4 to 52.8% (RS 29: 45.1%; ICSR 89058: 46.9%), metabolizable energy from 7.5 to 8 MJ kg^{-1} (RS 29: 6.5; ICSR 89058: 6.9) and lignin content from 1.7 to 2.8% (RS 29: 3.5 %).

Brown midrib sources trial: Six different *bmr* sources i.e. *bmr*1, *bmr* 3, *bmr* 6 (5 no.), *bmr* 7, *bmr* 8 and *bmr* 12 were evaluated for agronomic traits during 2009 rainy season along with four white midrib controls and a sweet sorghum variety. Compared to the best control (RS 29: 4.5 t ha^{-1}), the grain yield ranged from 3.0 to 3.5 t ha^{-1} in *bmr* 12, *bmr* 6 and *bmr* 1. In these three sources, plant height varied from 1.3 to 2.1 m (RS 29: 1.9 m), days to 50% flowering from 61 to 66 days (RS 29: 68 days) and agronomic score from 2.3 to 5.0 (RS 29: 3.0). Biochemical analysis of these lines is under progress.

Sweet sorghum forage trial: Thirteen promising sweet sorghum and forage sorghum genotypes were evaluated in a forage trial during the 2009 rainy season along with the check SSG 59-3. Compared to trial mean sugar yield of 1.0 t ha^{-1}, two sweet sorghum varieties ICSV 93046 (2.3 t ha^{-1}) and ICSV 700 (2.1 t ha^{-1}) were significantly superior. ICSV 93046 had a plant height of 2.9 m, fresh stalk weight of 36.9 t ha^{-1} and a Brix% of 18.4, while ICSV 700 had a plant height of 3.1 m, fresh stalk weight of 36.0 t ha^{-1} and a Brix% of 19.0.

Belum VS Reddy, P Srinivas Rao and A Ashok Kumar

Milestone 5A.1.1.2 Five male-sterile lines resistant each to grain mold and shootfly developed (BVSR/RPT/HCS/RS, 2008)

Achievement of Output Target:
50%
The parental lines are continuously evaluated for shootfly resistance, and the resistance needs to be further transferred into elite lines for use in hybrid production.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Evaluation of maintainer lines for resistance to sorghum shootfly, *Atherigona soccata:* Forty-three maintainer lines along with resistant and susceptible checks were evaluated during the rainy season 2009 for shootfly resistance. Data were collected for deadheart incidence at 21 days after seedling emergence. Deadheart incidence ranged from 11.1 to 84.9%. Among the 13 lines of the A$_1$ cytoplasm, the maintainer lines PTBA1 5, PTBA1 5, PTBA1 13, PTBA1 7, PTBA1 12, and PTBA1 3 suffered 11.2 to 36.3% deadhearts compared to 53.1% in

Swarna, and 19.4% in IS 18551. Among the 15 maintainer lines of the A_2 cytoplasm deadheart incidence ranged from 14.3 to 81.5%, and the maintainer line ABT 6 suffered 41.4% deadhearts compared to 80.1% in Swarna, and 14.3% in IS 18551.

Evaluation of new advanced maintainer lines for resistance to sorghum shootfly, *Atherigona soccata*: Fifteen maintainer lines of A_1 cytoplasm along with resistant and susceptible were evaluated for resistance to shootfly, *A. soccata* during the 2009 rainy season. Deadheart incidence ranged from 18.3 to 85.9%, and the maintainer lines 31103-2, 31109-1, 3119-2, 31117-1, ABT 6 suffered 27.2 to 41.2% deadhearts compared to 58.7% in Swarna, and 18.3% deadhearts in IS 18551.

HC Sharma, A Ashok Kumar and Belum VS Reddy

Milestone 5A.1.1.3 Five new high-yielding and large grain male-sterile lines in diverse backgrounds developed (BVSR/HDU, 2009)

Achievement of Output Target:
85%
A wide array of material ranging from F_2 to BC_5 stages was developed from which a number of male-sterile lines can be identified in diverse backgrounds for rainy and postrainy season adaptations. Thirty eight BC_4s were selected (with A_1 cytoplasm) for high yield and bold grain during the 2008 postrainy season. Here on, it takes 2-3 years for identifying high yielding large-seeded male-sterile lines with postrainy season adaptation.

Participating Countries:
India, Philippines and Mali

Participating Partners:
Nil

Progress and Results:
Dual- purpose B-line development

Rainy season adaptation: During the 2009 rainy season, 272 B-lines that include 149 B-lines in BC_5 stage (110 from BxB lustrous group and 39 from BxB non-lustrous group) 58 B-lines in BC_4 stage (10 from lustrous group, 2 from non-lustrous group, 11 from postrainy lustrous group, 32 from high yielding, grain mold tolerant group and 3 from high yielding non lustrous group) 22 B-lines in BC_2 stage: 3 from lustrous group and 19 from high yielding group) and 43 B-lines in BC_1 stage (from B×B high yielding group) on A_1 cytoplasm were selected for high grain yield and rainy season adaptation. Further, 163 F_7s were selected for grain yield and agronomic desirability and testcrossed. To diversify the hybrid parents for rainy season adaptation, 251 F_6s, 26 F_3s and 2180 F_2s were selected based on grain yield and agronomic desirability. From the crosses made between grain mold resistant lines and high-yielding B-lines, 33 F_2s were selected, from the crosses made between shootfly resistant B-lines and high yielding sweet sorghum B-lines, 55 F_2s were selected, from the crosses made between high yielding B-lines, postrainy varieties, sweet sorghum germplasm lines and breeding lines, 120 F_2s were selected.

Postrainy season adaptation: During the 2008 postrainy season, 38 B-lines at BC_4 stage of their conversion into A-line were selected (with A_1 cytoplasm) based on the crosses involving high-yielding B-lines, postrainy B-lines, shootfly resistant B-lines and postrainy varieties for high yield and bold grain and they are being evaluated in a postrainy B-lines trial during the 2009 postrainy season.

From 2100 F_5 progenies evaluated, a total of 904 progenies were selected and advance to F_6 based on the grain yield, grain size and luster during the 2008 postrainy season. These included 180 F_6 progenies derived from the crosses made between Gidda Maldandi and high yielding B-lines (HYB) (these included crosses between Gidda Maldandi x 296B, Gidda Maldandi × HYB × HYB, Gidda Maldandi × postrainy B-lines, Gidda Maldandi × HYB × M 35-1 bulk, Gidda Maldandi × HYB × postrainy variety), 277 F_6 progenies derived from the crosses made between postrainy landrace varieties and HYB, 61 F_6 progenies derived from the crosses made between postrainy varieties and high yielding B-lines, 155 F_6s derived from the crosses made between M 35-1 and HYB and 413 F_6s derived from the crosses made between high yielding B-lines.

From the crosses between lustrous germplasm lines, HYB and postrainy varieties, 322 selected progenies were advanced to F_5 based on grain yield, grain size and grain luster from 487 F_4 progenies evaluated during the 2008 postrainy season.

A total of 177 F_4 progenies were developed based on grain boldness and luster and grain yield from 789 F_3 progenies evaluated during the 2008 postrainy season. These included 144 F_4 progenies derived from postrainy season varieties × HYB and 33 F_4 progenies derived from landrace varieties × postrainy B-lines and postrainy R-lines.

Dual- purpose R-line development

Rainy season adaptation: From the crosses made between HYB × HYB, M 35-1 bulk × HYB, Gidda Maldandi × HYB, high yielding germplasm lines × HYB, 141 F_7s were developed based on grain yield and rainy season adaptation from 978 F_6s evaluated. From the crosses involving high yielding R-lines and varieties, 119 F_6s were selected from 352 F_5s evaluated, 36 F_6s from 401 F_5s evaluated (with sweet sorghum and grain Fe and Zn traits introgressed), 52 F_5s were selected from 301 F_4s evaluated and 20 F_4s were selected from 129 F_3s evaluated. For various traits, F_1s were advanced to F_2s that included 30 F_2s derived from the crosses between shootfly resistant lines from germplasm and shootfly resistant varieties, 34 F_2s derived from three-way crosses made between high yielding lines and 54 F_2s derived from the crosses made between postrainy adaptation F_1s and Gidda Maldandi, Dagidi solapur (1, 2, 3), SPV 1411, SPV 1359, Barshizoot.
Postrainy season adaptation: From the crosses made between postrainy R-lines, 53 F_4s were selected from 18 F_3s evaluated with selection for bold grain, luster and grain yield. From the crosses made between postrainy variety × variety and from postrainy variety × HYB, 166 F_5s were selected from 157 F_4s evaluated. From 725 F_5s evaluated during the 2008 postrainy season, 502 F_6s were selected based on grain yield, bold grain and postrainy season adaptation. These included 326 F_6s selected from postrainy RxR crosses, 6 F_6s from postrainy variety × variety crosses, 19 F_6s from Gidda Maldandi x postrainy variety crosses and 151 F_6s from postrainy germplasm lines × postrainy varieties crosses. The selected F_4s, F_5s and F_6s are being evaluated during the 2009 postrainy season.

Sweet sorghum:

Rainy season adaptation: A total of 1373 F_3s (from 299 F_2s) derived from crosses between sweet sorghum improved R-lines, 637 F_4s (from 222 F_3s), 1355 F_5s (from 573 F_6s) 234 F_5s (from144 F_4s) were selected for high Brix% (above 17%) and high biomass during the 2009 rainy season.

B-lines development: From a total of 307 F_4s derived from the crosses involving high yielding B-lines, sweet sorghum B-lines and sweet sorghum varieties, 205 F_5s were selected during the 2008 postrainy season based on stem juiciness, Brix%, high biomass and good grain yield for sweet sorghum B-lines development. A total of 5 F_4s (from 24 F_3s) were obtained during the 2008 postrainy season from the crosses between sweet sorghum varieties and sweet sorghum germplasm lines with selection for stalk juiciness, Brix% and high biomass. A total of 14 F_3s involving the crosses made between high yielding B-lines, high yielding R-lines and sweet sorghum improved R-lines are being advanced during the 2009 postrainy season.

Postrainy season adaptation: From a total of 1234 F_4s derived from the crosses made involving sweet sorghum varieties and sweet sorghum germplasm lines, 906 F_5s were selected for stalk juiciness and high biomass during the 2008 postrainy season. A total of 418 F_4s (from 333 F_3s) and 396 F_3s (from 212 F_2s) were selected for stalk juiciness, Brix% and high biomass during the 2008 postrainy season. From the crosses made between sweet sorghum landraces, sweet sorghum varieties, East and West African landraces, high biomass lines, 296 F_2s were harvested with selection for high Brix% (18 to 20) and are being advanced during the 2009 postrainy season.

From a total of 212 F_3s derived from the crosses involving new sweet sorghum varieties and sweet sorghum germplasm lines, 482 F_4s were selected for Brix% (18-20) and high biomass during the 2008 postrainy season.

Belum VS Reddy and P Srinivasa Rao

Milestone 5A.1.1.4 Four new male-sterile lines resistant each to shootfly and grain mold in diverse backgrounds developed (AAK/BVSR/RPT/HCS, 2010)

Achievement of output target (%):
80%
Developed 12 B-lines in BC_6 stage and 13 B-lines in BC_5 stage for post rainy season adaptation, 228   B-lines in BC_5 stage for rainy season adaptation using the shootfly resistant parents and 58 B-lines at BC_5 sage for grain mold resistance which needs to be evaluated.

Participating Countries:
India

Participating Partners:
Nil

Progress/Results:
Shootfly resistant male-sterile lines development program: Selected 12 postrainy season adapted shootfly resistant B-lines at BC_6 stage of their conversion into A_1 CMS-based A-line, 13 B-lines at BC_5 stage (8 on A_1 and 5 on A_2) and 230 B-lines at BC_2 stage (on A_1), 9 B-lines at BC_5 stage on A_1, 7 B-lines at BC_4 stage (5 on A_1 and 7 A_2) and 108 B-lines at BC_1 stage on A_1 in breeding block. These progenies will be further evaluated and advanced in postrainy season for stability of A/B maintenance.

Selected 228 rainy season adapted shootfly resistant B-lines at BC_5 stage of their conversion into A-lines (127 on A_1 CMS system and 101 A_2 CMS system), 4 B-lines at BC_2 stage (on A_1). From conversion and evaluation of 96 B-lines at BC_4 stage (54 on A_1 and 42 A_2), 5 B-lines at BC_1 stage on A_1 (breeding block), and also selected a total of 347 TCs from 337 F_5s and 42 F_4s of shootfly resistant and high yielding B-line progenies, and advancing and test crossing of 98 F_5s derived from the crosses between sweet stalk progenies and high-yielding established B-lines for further selection for rainy and postrainy season adaptations with shootfly resistance. These progenies are under further evaluation and conversion in postrainy season.

Grain mold resistant male-sterile lines development program: Conversion and evaluation of grain mold resistant 58 B-lines at BC_5 stage of their conversion into A-lines (46 on A_1 and 12 on A_2), 11 B-lines at BC_4 stage (4 on A_1 and 7 on A_2) and 56 F_6 progenies and 13 F_7 progenies with testcrosses in the 2008 postrainy season resulted in the selection of 40 B-lines at BC_6 stage on A_1 and 11 B-lines at BC_6 stage on A_2, 5 B-lines at BC_5 stage (1 on A_1 and 4 A_2) and 41 B-lines at BC_1 stage which were evaluated in 2009 rainy season and selected 11 B-lines at BC_7 stage and 4 B-lines at BC_6 stage on A_2, and 31 B-lines at BC_2 stage on A_1 for further evaluation in 2009 postrainy season. The 40 B-lines at BC_6 stage on A_1 evaluated in Grain mold preliminary B-line progenies trial under 5A.1.1.2.

Evaluated 85 TCs (68 with white grain and 17 colored grain) in RCBD (3 reps) for grain mold resistance in screening block and in nursery for conversion into A/B-pairs in breeding block in 2009 rainy season. The PGMR score ranged from 3.8 to 7.5 in the 68 white grain progenies evaluated in screening block under sprinkler irrigation. Eleven progenies showed PGMR below 5.0. Selected 49 white grain color BC_1s from breeding nursery based on agronomic performance. Seventeen colored grain progenies ranged from 5.7 to 8.1 for PGMR score in screening block when evaluated under sprinkler irrigation. Selected 8 colored grain BC_1s from breeding nursery based on agronomic performance.

Advancing of 215 TCs for B-line development and 340 TCs for R-line development in the 2008 postrainy season resulted in the selection of 105 B-lines at BC_1 stage of their conversion into A-lines (23 from high Fe and Zn lines x high yielding B and R-line crosses, 37 from B x B non lustrous group) for B-line development; 45 B-lines at BC_1 stage of their conversion into A-lines (4 from R x R lustrous group and 41 from R x R non lustrous group) from crosses made for R-line development. All these were evaluated in 2009 rainy season and selected 84 B-lines at BC_2 stage of their conversion into A-lines (18 high Fe and Zn lines x high yielding B and R-line crosses and 11 high Fe and Zn lines x high yielding B and B-line crosses; 29 B x B non lustrous group for B-line development; 4 B-lines at BC_2 stage of their conversion into A-lines R x R lustrous group and 22 R x R non lustrous group) respectively for further evaluation in 2009 postrainy season.

Thirty-six restorer lines including Swarna as the susceptible check, and IS 18551 as a resistant check were tested for shootfly resistance using the interlard fishmeal technique. Data were recorded on shootfly deadhearts 21 days after seedling emergence, when the differences

between the resistant and susceptible checks were maximum. Shootfly deadhearts ranged from 24.0 to 96.8%, and genotypes RPRT 22, RPRT 63, and REVRT suffered 38.9 to 43.9% deadhearts compared to 24.0% deadhearts in IS 18551, and 78.4% deadhearts in Swarna.

A Ashok Kumar, Belum VS Reddy, HC Sharma and RP Thakur

Milestone 5A.1.1.5 New male-sterile lines (4) introgressed with three selected shootfly resistance QTLs in 296B and BTx 623 backgrounds completed (CTH/SPD/BVSR/HCS/SS, 2008)

Achievement of Output Target:
100%
QTLs associated with shootfly resistance have been identified, and the shootfly resistance QTLs transferred to susceptible hybrid parents using MAS – 5 QTLs in BTx623 background and 4 in 296B background. A-line conversion of selected QTL introgression NILs has been completed.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Putative quantitative trait loci (QTLs) for shootfly resistance were mapped previously using recombinant inbred line (RIL) progeny sets from crosses of two different elite, but susceptible lines (296B and BTx623) with a single resistant landrace accession (IS 18551). During the course of a PhD thesis research, marker-assisted backcrossing was used to transfer five putative QTLs for resistance to shootfly from IS 18551 to BTx623, and four of these to 296B. Four backcross generations (BC_1F_1 through BC_4F_1) were advanced with SSR marker-based foreground selection to select plants heterozygous for IS 18551 alleles at markers flanking five shootfly resistance QTL target regions [on SBI-01, SBI-07, SBI-10 (associated with glossiness intensity), and the short and long arms of SBI-05 (associated with leaf trichome density)]. Simultaneous background selection was also followed to recover recurrent parent genome in non-target regions. In the BC_4F_2 generation, plants homozygous for IS 18551 marker alleles at specific target regions were identified and selfed. Five sets of BC_4F_3 near-isogenic line (NIL) pairs in BTx623 background were field screened in the rainy seasons of 2006, 2007, 2009 and the postrainy season of 2006/07 at ICRISAT-Patancheru. Similarly, four sets of NIL pairs in 296B background were evaluated (we did not recover the SBI-10 trichome QTL introgression in 296B background).

In both genetic backgrounds, significant and substantial differences were observed between resistance QTL introgression lines and their near-isogenic recurrent parents for shootfly deadhearts incidence, seedling glossiness score, and seedling leaf blade trichome density (BTx623 background only). Association of introgressed genomic regions with characters previously associated with shootfly resistance (i.e., glossiness intensity and leaf trichome density) confirmed roles of genomic regions on SBI-05 (associated with glossiness and seedling vigor), and SBI-10 (associated with glossiness, trichome density and seedling vigor) in control of host plant resistance to this important sorghum pest. Further, for each of the five introgression target regions several of the single-QTL introgression lines homozygous for IS 18551 SSR marker alleles flanking the target QTL exhibited significantly improved shootfly reaction compared to their susceptible recurrent parents, BTx623 and 296B. Marker-assisted A-line conversion of selected QTL introgression lines has been completed for the short arms of SBI-05 (296B and BTx623) and SBI-10 (BTx623 only). These shootfly resistance QTL introgressions can now be pyramided in BTx623 and 296B backgrounds and selected individual introgression lines used as donors for applied marker-assisted backcross improvement of shootfly resistance of diverse sorghum hybrid parental lines.

SP Deshpande, T Jyothi, CT Hash and HC Sharma

Output target 5A.2 A diverse range of trait-specific sorghum breeding lines and populations with morphological diversity and resistance to shootfly, stem borer and grain mold (2011)

Activity 5A.2.1 Generating new breeding lines with resistance to disease and insect pest resistance, and mapping of QTL and assessment of their effects on resistance levels for these traits

Milestone 5A.2.1.1 Forty F_4 lines developed for resistance to each of grain mold and shootfly (AAK/BVSR/RPT/HCS/RS, 2010)

Achievement of output target:
90%
A total of 300 F_4s for shootfly resistance and 400 F_4s for grain mold resistance were developed.
Participating Countries:
India

Participating Partners:
Nil

Progress/Results:
A total of 438 F_3s derived from the crosses between adapted breeding lines and unadapted germplasm lines were evaluated in the 2008 postrainy season and 300 F_4s were developed and these were screened separately for shootfly resistance and grain mold resistance in 2009 rainy season in respective screening blocks. These progenies showed shootfly dead hearts % (SFDH%) ranging from 5 to 100, where as resistant control IS 18551 showed 30% shootfly dead hearts and susceptible control Swarna showed 91% shootfly dead hearts. Seven F_4s showed shootfly dead hearts below 50% and among them one F_4 showed only 5%. For grain mold resistance, the PGMR score in the

progenies ranged from 1.5 to 7.6. Fifty nine F_4s showed PGMR below 4.0. The same set of F_4s was evaluated in breeding block and selected 254 F_5s based on agronomic desirability.

Advanced 113 F_2s developed from crosses involving high yielding and grain mold tolerant parents and developed 332 F_3 progenies in 2008 postrainy season and the same were evaluated in 2009 rainy season for B-line progenies development as a nursery for grain mold resistance in screening block and for test crossing in breeding block. These progenies had 2.0 to 7.6 for PGMR score. Ninety seven F_3s showed PGMR score below 4.0. Selected 400 F_4s from breeding nursery based on agronomic desirability for further evaluation in 2009 postrainy season.

Selected 89 F_2s in 2008 postrainy season for B-line development with shootfly resistance and evaluated in 2009 rainy season under low fertility and normal shootfly conditions. Also developed 403 F_3s and planted in 2009 postrainy season for further advancement and selection for B/R progenies development. Development of 50 F_1s using new sources (10) for shootfly resistance from germplasm and high yielding B-lines in the postrainy season is underway.

In the advanced progeny (F7 to F8) trial, 167 lines including Swarna, and IS 18551 as the susceptible and resistant checks, respectively, were evaluated for resistance to shootfly, *A. soccata* in a randomized complete block design in three replications. Data were recorded on shootfly deadhearts at 21 days after seedling emergence. Deadheart incidence in this trial varied from 20.60 to 89.53%, and 27 lines suffered <40% deadheart incidence compared to 69.11% deadhearts in Swarna, and 21.0% deadhearts in IS 18551.

<div align="right">A Ashok Kumar, Belum VS Reddy, RP Thakur, HC Sharma and Rajan Sharma</div>

Milestone 5A.2.1.2 Two F_6 RIL populations (300 lines each) developed for mapping grain mold resistance (CTH/BVSR/SPD/RPT/RS, 2008)

Achievement of Output target:
>75%
F_5 progenies from 3 RIL populations were harvested at the end of the 2009 rainy season, threshed and sown in the postrainy season of 2009-10 for another generation of advancement by modified single-seed descent with selfing.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Following harvest of the 2009 rainy season nursery, 96F_4 and 1026F_5 recombinant inbred lines from these crosses were sown in the 2009-10 postrainy season nursery for further generation of selfing, with the intention of having F_6 RIL progeny sets available for genotyping and phenotyping by the onset of the 2010 rainy season:

<div align="right">CT Hash, Belum VS Reddy, SP Deshpande, RP Thakur and R Sharma</div>

Milestone 5A.2.1.3 RIL for grain mold resistance from two mapping populations phenotyped and genotyped, and QTL maps developed using 300 markers (BVSR/CTH/SPD/RPT/RS, 2010)

See above: This 2010 milestone can be met provided that funding to genotype and phenotype the F6 RIL populations is made available once harvest of the 2009-10 postrainy season nursery has been completed.
<div align="right">Belum VS Reddy, CT Hash, SP Deshpande,
RP Thakur, R Sharma and S Senthilvel</div>

Milestone 5A.2.1.4 Putative QTL for stem borer resistance and its components based on RIL from two crosses identified (HCS/CTH/SPD, 2009).

Achievement of Output Target:
50%
Mapping population for stem borer resistance has been phenotyped, and genotyping and data analysis are in progress.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:
To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population (270 lines) from cross ICSV 745 x PB 15220 was evaluated for stem borer resistance under artificial infestation in the field as a part of a thesis research. It also included resistant (IS 2205) and susceptible checks (ICSV 1), and the parents (PB 15220 and ICSV 745). Data analysis is in progress to identify QTLs associated with resistance to *C. partellus*.

<div align="right">HC Sharma, CT Hash and SP Deshpande</div>

Milestone 5A.2.1.4 Putative QTLs for stem borer resistance and its components based on RIL from two crosses identified (HCS/CTH/SPD, 2009)

Achievement of Output Target:
100%
The second mapping population for stem borer resistance has been phenotyped during two rainy seasons with artificial infestation and one rainy season under protected conditions. SSR genotyping to extend the linkage map was completed, initial QTL and analysis of the single-season and across season data sets for the two seasons of infested trials have been completed.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:
To detect quantitative trait loci (QTLs) for stem borer resistance, a set of 266 SSR-skeleton-mapped $F_{9:10}$ sorghum recombinant inbred lines (RILs), derived from cross ICSV 745 (susceptible) × PB 15520 (resistant), were field evaluated (under artificially-infested conditions at ICRISAT-Patancheru during the 2007 and 2008 rainy seasons) for five traits related to spotted stem borer resistance — deadhearts incidence (%), stem tunneling (cm), and leaf feeding damage, recovery resistance and overall resistance scores — as well as a range of other traits related to agronomic performance and product quality. The linkage map for this population was extended to 90 SSR markers, dramatically improving genome coverage to 1289 cM (Haldane units) as well as improving colinearity of this linkage map with those previously published for sorghum. Twenty-nine putative QTLs for five traits related to spotted stem borer resistance were detected across the two environments. Most important were a cluster of stable putative QTLs detected on chromosome SBI-07 (between markers *Xisep0829* and *XSbAGB02*), which consistently contributed to observed variation in host plant resistance to spotted stem borer. This cluster of QTLs accounted for large proportions (5 to 25%) of observed phenotypic variation, and exhibited significant additive effects, for each of the specific resistance-related traits. This genomic region also contains loci contributing number of nodes per main stem, plant height *(dw3)*, and agronomic score, along with a modifier of sorghum foliage color (tan *vs.* non-tan). *In-silico* comparison with maize indicated synteny of this sorghum genomic region with part of maize chromosome 1 previously associated with stem borer resistance, strengthening support for the role of this sorghum genomic region in stem borer resistance, and suggesting it as a good candidate for marker-assisted selection to improve spotted stem borer resistance. A second region on chromosome SBI-04 (flanked by marker loci *Xtxp041* and *Xisp10229*) was associated with leaf angle, testa pigmentation, mesocarp thickness, and agronomic score. Erect leaf angle, thick mesocarp, and pigmented testa from stem borer resistance donor PB 15520 appeared to be inherited as a unit. This genomic region was also associated with a stem tunneling QTL of modest effect (6% of observed variation) in the across-season data sets and variation in seedling vigor and seedling basal pigmentation scores in the 2008 rainy season and across-season data sets. A larger segregating population will be required to demonstrate whether the strong association between leaf angle, testa pigmentation and mesocarp thickness is simply due to tight genetic linkage or a result of pleiotropy. In any case, the favorable allele for stem tunneling in this region was that from the susceptible parent, so reduced stem tunneling at this QTL was associated with non-erect leaf blades, non-pigmented testa, and thin mesocarp — providing a simple visual method to select for the favorable allele in the absence sufficient stem borer infestation.

MT Vinayan, CT Hash, SP Deshpande and HC Sharma

Milestone 5A 2.1.5 Comparative mapping of QTL for stem borer resistance in sorghum and maize completed (HCS/SPD/DAH/CTH, 2009)

Achievement of Output Target:
100%
In-silico comparisons of newly mapped sorghum stem borer resistance QTLs with published maize stem borer resistance QTLs have been completed.

Participating Countries:
India

Participating Partners:
Tamil Nadu Agricultural University

Progress/Results:
As it has proven impossible to successfully introduce from CIMMYT a maize RIL mapping population segregating for stem borer resistance, we were restricted to in silico comparisons of stem borer resistance newly detected in sorghum (effective against *Chilo partellus*) and with those previously published for maize (effective against several species of stem borers in the genera *Ostrinia* and *Diatraea*). Based on the field screening of sorghum RIL progenies described above, a cluster of stable putative QTLs for five traits directly associated with stemborer resistance [deadhearts incidence (%), stem tunneling (cm), and leaf feeding damage, recovery resistance and overall resistance scores] were detected on sorghum chromosome SBI-07 (between markers *Xisep0829* and *XSbAGB02*), which consistently contributed to observed variation in host plant resistance to spotted stem borer. This cluster of QTLs accounted for large proportions (5 to 25%) of observed phenotypic variation, and exhibited significant additive effects, for each of the specific resistance-related traits. This genomic region also contains loci contributing to control of the number of nodes per main stem, plant height *(dw3)*, and agronomic score, along with a modifier of sorghum foliage color (tan *vs.* non-tan). *In-silico* comparison with maize indicated synteny of this sorghum genomic region with part of maize chromosome 1 previously associated with stem borer resistance, strengthening support for the role of this sorghum genomic region in stem borer resistance, and suggesting it as a good candidate for marker-assisted selection to improve spotted stem borer resistance.

MT Vinayan, CT Hash, SP Deshpande and HC Sharma

Milestone 5A.2.1.6: Effectiveness of two best QTL for resistance to shootfly in two genetic backgrounds demonstrated (CTH/SPD/SS/HCS/BVSR, 2007)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
Osmania University

Progress/Results:
Five sets of BC$_4$F$_3$ near-isogenic line (NIL) pairs in BTx623 background were field screened in the rainy seasons of 2006, 2007, 2009 and the postrainy season of 2006/07 at ICRISAT-Patancheru. Similarly, four sets of NIL pairs in 296B background were evaluated (we did not recover the SBI-10 trichome QTL introgression in 296B background).

In both genetic backgrounds, significant and substantial differences were observed between resistance QTL introgression lines and their near-isogenic recurrent parents for shootfly deadhearts incidence, seedling glossiness score, and seedling leaf blade trichome density (BTx623 background only). Association of introgressed genomic regions with characters previously associated with shootfly resistance (i.e., glossiness intensity and leaf trichome density) confirmed roles of genomic regions on SBI-05 (associated with glossiness and seedling vigor), and SBI-10 (associated with glossiness, trichome density and seedling vigor) in control of host plant resistance to this important sorghum pest. Further, for each of the five introgression target regions several of the single-QTL introgression lines homozygous for IS 18551 SSR marker alleles flanking the target QTL exhibited significantly improved shootfly reaction compared to their susceptible recurrent parents, BTx623 and 296B. The two most effective shootfly resistance QTLs from donor parent IS 18551 appears to be those on the long arm of SBI-10 and the short arm of SBI-05.

Special Project Funding:
None

<div align="right">SP Deshpande, T Jyothi, S Senthilvel, CT Hash,
HC Sharma and Belum VS Reddy</div>

Milestone 5A.2.1.7 Comparisons of lines with single-QTL introgressions and QTL pyramided in two genetic backgrounds for shootfly resistance completed (HCS/BVSR/CTH/SPD, 2010)

See Above: Funding for additional pyramiding of the validated shootfly resistance QTLs is required if this is to be met for any pairs of the five validated shootfly resistance QTLs except for the pair on the short arm and long arm of SBI-05, for which this has already been completed in both genetic backgrounds (296B and BTx623).

<div align="right">SP Deshpande, CT Hash, HC Sharma and Belum VS Reddy</div>

Milestone 5A.4.1.3: Relative contributions of host and environmental factors in mold development assessed (RPT/RS/BVSR, 2010)

Achievement of Output Target:
80%
Contributions of host factors to mold development have been studied, and both morphological and agronomic factors are known to influence host resistance and mold development. Among weather variables, panicle wetness and RH are also known to influence mold development. Studies on influence of temperature & RH on mold development need to be confirmed.

Participating Countries:
India

Participating Partners:
None

Progress/Process:
Host factors, such as, days to 50% flowering and plant height, panicle type, glumes coverage, glumes and grain color have some direct and indirect correlation with grain mold resistance as reported last year.

Influence of different temperature and RH regimes on grain mold development. This was studied by incubating the artificially inoculated plant at different temperatures and RH regimes in the growth chambers for 15 days. Two cultivars Bulk Y and 296 B were selected for the experiment. Panicles were inoculated at >80% anthesis with conidial suspensions (1×10^6 spores mL^{-1}) of a *Fusarium* isolate and exposed to wetness for 24 hr after inoculation in greenhouse. The inoculated plants were incubated at 25 C (RH=85-95%), 30 (RH=80-90%), 35 °C (RH=60-75%) and 40 C (RH=50-60%) for 15 days. Following incubation plants were shifted to greenhouse both under mist and non-mist conditions for grain mold development. Initial observations indicated abortion of florets, poor grain development and absence of any visible mold development on panicles exposed to 35 and 40 °C. The grains from the panicles have been harvested and are being plated to determine the levels of mold infection, if any.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

<div align="right">RP Thakur, Rajan Sharma, Belum VS Reddy</div>

Output target 5A.5 Information on association between CMS and agronomic traits, and between molecular diversity and yield heterosis in sorghum (2009)

Activity 5A.5.1 ***Evaluation of iso-cytoplasmic hybrids for grain yield and agronomic traits***

Milestone 5A.5.1.1 Twelve hybrids with four diverse CMS systems compared for agronomic traits and resistance to shootfly and grain mold (BVSR/RPT/RS/HCS, 2009)

Achievement of Output Target:
90%
Hybrids in different CMS backgrounds have been evaluated, and data analysis is in progress.

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Thirty-two F_1 hybrids and their parents, including Swarna as the susceptible check, and IS 18551 as a resistant check were tested for shootfly resistance using the interlard fishmeal technique. There were three replications in a randomized complete block design. Data were recorded for shootfly deadhearts 21 days after seedling emergence, when the differences between the resistant and susceptible checks were maximum. Shootfly deadhearts ranged from 39.95 to 93.94% in the F_1 hybrids and their parents, 39.95% in IS 18551, and 78.85% in Swarna. The hybrids SFB53-3-1-1 x PVK 801 and SFB53-3-1-1 x S 35, and the restorer line 34217 suffered 30.47 to 44.1%% deadhearts compared to 78.85% deadhearts in Swarna and 39.95% deadhearts in IS 18551.

Special Project Funding:
Public Private Consortium for Sorghum Research; IFAD project on Sweet Sorghum

HC Sharma, Ashok Kumar and Belum VS Reddy

Output target 2009 5A.6 High-yielding and good combining sorghum hybrid parents developed for postrainy season adaptation

Activity 5A.6.1 Developing high-yielding and good combining sorghum hybrid parents for postrainy season adaptation

Milestone 5A.6.1.1 Five each of high-yielding and good combining sorghum male-sterile lines and restorer lines for postrainy season developed (BVSR, 2009)

Achievement of Output Target:
100%
From the evaluation of postrainy season hybrids and hybrid parents, promising parents (12 R-lines) that give heterotic hybrids have been identified. The information on A/B-lines is presented in 5 A. 1.1.1

Participating Countries:
India

Participating Partners:
Nil

Progress/Results:
Postrainy advanced hybrid trial (PRAHT): Fifteen promising postrainy season adapted hybrids selected from preliminary hybrid trial conducted during 2007-08 postrainy season were evaluated in a three replicated RCBD during the 2008 postrainy season along with the controls, M 35-1, SPV 1411 and SPH 840. The hybrid, ICSA 563 × ICSR 161 was the highest grain yielder with 5.5% superiority over the best performing control, M 35-1 (4.43 t ha^{-1}). However 11 hybrids with grain yield ranging from 3.19 to 4.43 t ha^{-1} were comparable to it. Among the 11 hybrids, grain size (g 100^{-1} grains) ranged from 3.37 to 4.07 (M 35-1: 3.79, SPV 1411: 3.81), grain luster score (taken on a 1 to 3 scale, where 1= most lustrous and 3= least lustrous) ranged from 2.0 to 3.0 (M 35-1: 2.0, SPV 1411: 2.3), days to flowering ranged from 69 to 73 days (M 35-1: 75 days, SPV 1411: 78 days), plant height ranged from 1.6 to 2.6 m (M 35-1: 2.6 m, SPV 1411: 2.5 m).

Postrainy advanced varietal trial (PRAVT): A total of 14 postrainy season adapted varieties selected from postrainy adapted preliminary varietal trial during 2007-08 postrainy season were evaluated in RAVT during the 2008 postrainy season in a three-replicated RCBD along with the controls M 35-1 and SPV 1411. Eight varieties with a grain yield ranging from 3.46 to 4.05 t ha^{-1} were comparable to the best performing control M 35-1 (4.5 t ha^{-1}) for grain yield. Among these three varieties had a better grain luster (score: 1) than M 35-1 and SPV 1411 (score: 1.3) while for grain size seven of them (3.61 to 4.10 g 100^{-1} grains) were comparable to M 35-1 (4.02 g 100^{-1} grains). They flowered in 75 to 79 days (M 35-1: 75 days, SPV 1411: 76 days) and had a plant height of 2.4 to 2.9 m (M 35-1: 2.6 m, SPV 1411: 2.5 m).

Postrainy elite R-lines trial (PREVRT): Eight postrainy season adapted restorer lines selected from advanced R-lines trial conducted during 2007-08 postrainy season were evaluated during the 2008 postrainy season in a three-replicated RCBD along with the controls M 35-1 and SPV 1411. Four varieties with a grain yield ranging from 4.2 to 4.6 t ha^{-1} were numerically superior to the best performing control M 35-1 (3.9 t ha^{-1}) by 8 to 18%. They were similar to M 35-1 for grain luster (score: 2) and had a grain size of 3.4 to 3.8 g 100^{-1} grains (M 35-1: 4.3 g 100^{-1} grains). They flowered in 75 to 79 days (M 35-1: 75 days) and had a plant height of 2.5 to 3.1 m (M 35-1: 2.6 m).

Postrainy preliminary R-lines trial (PRPRT): A total of 81 postrainy season adapted restorer lines selected from the F_7 progenies during 2007 postrainy season were evaluated in a RPRT during the 2008 postrainy season. The trial was conducted in a RCBD with 3 replications along with the controls NTJ 2 and RS 29. Fifteen R-lines with a grain yield ranging from 4.23 to 4.98 t ha^{-1} were comparable to the best performing control RS 29 (5.24 t ha^{-1}) for grain yield. The grain size (g 100^{-1} grains) among the lines varied from 2.07 to 3.21 (RS 29: 1.94

and NTJ 2: 2.78). These lines flowered in 71 to 85 days (RS 29: 87 days, NTJ 2: 75 days) and had a plant height of 1.3 to 2.2 m (RS 29: 1.8 m, NTJ 2: 2.2 m). Two lines had a grain luster score of 2 (RS 29 and NTJ 2: 3).

Special Project Funding:
ICRISAT-Private Sector Sorghum Hybrid Parents Research Consortium

<div align="right">Belum VS Reddy</div>

Output target 2009 5A.7 High-yielding dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents

Activity 5A.7.1 Developing dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents

Milestone 5A.7.1.1 Six new dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents developed (BVSR, 2009)

Achievement of Output Target:
100%
From the evaluation of forage/sweet sorghum hybrids and hybrid parents, promising parents (A/B-lines and R-lines) that give heterotic hybrids have been identified.

Participating Countries:
India

Participating Partners:
Indian NARS (Public and Private sector)

Progress/Results:
Sweet sorghum preliminary B-line trials (SSPBT): A total of 27 B-lines were evaluated for performance under terminal drought stress during the 2008 postrainy season along with the controls ICSB 38 and SSV 84 in RCBD with three replications. Of these, 19 lines with sugar yield ranging from 0.06 t ha^{-1} to 0.47 t ha^{-1} were superior to both the checks, ICSB 38 (0.06 t ha^{-1}) and SSV 84 (0.04 t ha^{-1}). The days to 50% flowering across these 19 lines ranged to 78 to 84 (ICSB 38: 78 days), plant height from 0.9 to 1.4 m (ICSB 38: 1 m) and Brix% from 9.2 to 14.6 (71%). The top five sugar yielding B-lines include SP 93135 (0.4 t ha^{-1}), SP 2781 (0.27), SP 54819-1 (0.26), SP 93037 and SP 93103 (0.2 t ha^{-1}) each.

Sweet sorghum advanced B-line trial (SSABT): Thirty three advanced B-lines selected previously were evaluated in SSABT during the 2008 postrainy season in RCBD with three replications for terminal drought tolerance along with the controls SSV 84 and CSH 22SS. Compared to the best performing control (SSV 84: 0.05 t ha^{-1}) for sugar yield SP08 2036-1, SP08 2065-3, SP08 1026-2, SP08 2060-2 and SP08 1035-2 ranging from 0.2 to 0.3 t ha^{-1} were significantly superior. Among these, the grain yield ranged between 0.9 to 2.2 t ha^{-1} (SSV 84: 2.5) and Brix% between 8 to 11.8% (SSV 84: 9.9%).

A total of 27 B-lines selected from the sweet sorghum preliminary B-lines trial and grain-based preliminary B-lines trial during the 2008 rainy season were evaluated in SSABT during the 2009 rainy season along with the controls ICSB 38 and SSV 84. The trial was conducted in RCBD in three replications. Though the B-lines did not out yield the varietal control SSV 84 (2.6 t ha^{-1}) for sugar yield, 26 of the 27 B-lines were numerically superior over the control ICSB 38. Of these 21 B-lines with a sugar yield ranging from 0.9 t ha^{-1} to 2.6 t ha^{-1} were significantly superior to ICSB 38 (0.5 t ha^{-1}). The days to 50% flowering among these 21 B-lines ranged from 67 to 83 days (ICSB 38: 68 days), plant height from 1.6 to 2.9 m (ICSB 38: 1.6 m) and Brix% from 16.0 to 20.5% (12.9%). The top five high sugar yielding B-lines include SP 93037 (2.6 t ha^{-1}), SP 85040-1-1 (2.3 t ha^{-1}), SP 85026-1-2 (2.2 t ha^{-1}), SP 54801-2 (2.0 t ha^{-1}) and SP 54819-2 (1.9 t ha^{-1}).

Sweet sorghum preliminary varietal trial (SSPVT): A total of 24 varieties selected from the sweet sorghum advanced progenies trial during the 2008 postrainy season were evaluated in SSPVT during the 2009 rainy season along with the controls CSH 22SS and SSV 84. The trial was conducted in RCBD in three replications. The variety SP 16438-1 with a sugar yield of 4.5 t ha^{-1} was significantly superior to the best performing control CSH 22SS (3.6 t ha^{-1}) while the varieties SP 16439-2 (3.8 t ha^{-1}) and SP 16440-3 (3.8 t ha^{-1}) were numerically superior over it. The varietal check SSV 84 had a sugar yield of 3.1 t ha^{-1}. Among the selected varieties, the days to 50% flowering ranged from 64 to 71 days (CSH 22SS: 64 days) while the Brix% from 15.7 to 17.0 (CSH 22SS: 16.8).

Sweet sorghum advanced varietal and restorer lines trial (SSAVRT): A total of 68 varieties/restorer lines selected from the sweet sorghum preliminary varietal and restorer lines trial during the 2008 rainy season were evaluated in SSAVRT during the 2009 rainy season along with the controls CSH 22SS and SSV 84. The trial was conducted in RCBD in three replications. Sixteen lines with a sugar yield ranging from 3.9 to 4.4 t ha^{-1} were comparable to the best performing control SSV 84 (3.98 t ha^{-1}). These varieties flowered in 69 to 89 days (SSV 84: 83 days), had a plant height ranging from 3.7 to 4.2 m (SSV 84: 4.0 m), Brix% ranging from 17.2 to 18.8 (SSV 84: 18.9).

Sweet sorghum advanced hybrid trial (SSAHT): A total of 42 hybrids selected previously were evaluated in SSAHT during the 2008 postrainy season along with the controls SSV 84, CSH 22SS and CSH25. Compared to the best performing control CSH25 and SSV 84 (0.3 t ha^{-1} each) for sugar yield, five hybrids ICSA675 x SP 4504-3 (0.8 t ha^{-1}), ICSA38 x SP 4511-2 (0.7 t ha^{-1}), ICSA675 x SP 4495 (0.7 t ha^{-1}), ICSA102 x ICSV 93046 (0.7 t ha^{-1}) and ICSA502 x SP 4511-2 (0.7t ha^{-1}) showed significantly higher sugar yields. Among these five hybrids, the grain yield ranging from 1.5 to 4.7 t ha^{-1} (2.2 t ha^{-1}) and Brix% from 9.8 to 15.0 (11.4%).

On-station evaluation of on-farm trial entries: The elite sweet sorghum hybrids and varieties identified from the breeding program are tested under on-farm conditions to find out their adaptation to the region of interest and the acceptability to the growers. The entries under on-farm testing are also evaluated in research station to find out the relative performance. Under this trial eight sweet sorghum hybrids (ICSA 84 × E 36-1, ICSA 38 × ICSV 700, ICSA 84 × SPV 1411, ICSA 675 × ICSV 700, ICSA 474 × SSV 74, ICSA 475 × NTJ 2, ICSA 702 × SSV 74 and ICSA 475 × SSV 74) and eight sweet sorghum varieties (SP 4511-3, SPV 422, SP 4487-3, SS 2016, SP 4495, SP 4511-2 and ICSV 93046) were evaluated along with the sweet sorghum variety controls SSV 84 and RSSV9, sweet sorghum hybrid control CSH 22SS and grain sorghum hybrid control CSH 25 in RCBD with three replications at four different stages i.e. flowering, dough, physiological maturity and late maturity in postrainy season 2008. Analysis of variance revealed that stage at harvest is highly significant for sugar yield, Brix%, stalk weight (t ha^{-1}), juice volume (kl ha^{-1}), and bagasse (t ha^{-1}). The mean of sugar yield is highest at physiological maturity (0.5 t ha^{-1}) followed by late maturity (0.5), dough stage (0.2) and 50% flowering (0.2). Brix% was highest at late maturity (14.7)

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while cane weight (16.5 t ha^{-1}) and juice volume (5.2 kl ha^{-1}) were highest at physiological maturity. Compared to the best control RSSV9 (0.5 t ha^{-1}) and the varietal check SSV 84 (0.3 t ha^{-1}) for sugar yield, ICSA731 x ICSV 93046 (1.3 t ha^{-1}), ICSA474 x SSV 74 (0.9 t ha^{-1}) were significantly superior. Among these varieties, SP 4511-2 recorded the highest sugar yield (0.8 t ha^{-1}). Similar trend was noticed in late maturity stage.

Eight sweet sorghum hybrids and seven sweet sorghum varieties were evaluated along with sweet sorghum variety control SSV 84 and sweet sorghum hybrid control CSH 22SS in a three-replicated RCBD design during the 2009 rainy season at ICRISAT-Patancheru. Based on the best performing control CSH 22SS (2.8 t ha^{-1}) for sugar yield, SP 4487-3 (2.9 t ha^{-1}) was numerically superior and significantly superior compared to the released sweet sorghum variety control SSV 84 (2.4 t ha^{-1}). The variety SPV 422 (2.8 t ha^{-1}) was significantly superior and the hybrids ICSA 84 × E 36-1 (2.6 t ha^{-1}) and ICSA 702 × SSV 74 (2.6 t ha^{-1}) were numerically superior over SSV 84. SP 4487-3 flowered in 88 days, had a plant height of 3.4 m and Brix% of 20.8 while SPV 422 flowered in 91 days, and had a plant height of 2.9 m and Brix% of 21.6.

On-farm evaluation of pre-released hybrids and varieties: During the 2009 rainy season, an on-farm trial was conducted to evaluate 18 entries that include newly developed sweet sorghum hybrids (7) and varieties (5) along with two controls CSH 22 SS (hybrid control) and SSV 84 (varietal control). The trial was planted in a RCBD with three replications in farmers fields (each field 0.2 ha in area) at Ibrahimbad cluster in Medak District, Andhra Pradesh, India. Data were collected on agronomic parameters and sweet stalk traits. Four hybrids and four varieties ranging from 17 to 20 for Brix% are 2 to 20% significantly superior to CSH 22SS (16%). Three varieties – SP 4511-2, SP 4511-3 and ICSV 93046 were on par with SSV 84 for Brix% (19). Another variety SPV 422 had sugar yield (2.47 t ha^{-1}) significantly (by 21%) higher than CSH 22 SS (1.89 t ha^{-1}) and on par with SSV 84 for sugar yield (2.47 t ha^{-1}) and grain yield (2.83 t ha^{-1}).

Evaluation of sweet sorghum varieties for shootfly resistance and downy mildew and anthracnose resistance: A total of 35 elite and 22 advanced sweet sorghum hybrids, 33 B-lines and 65 R-lines were evaluated in 2008 postrainy season; and a total of 56 elite and 46 advanced sweet sorghum hybrids, 32 B-lines and 70 R-lines were evaluated in 2009 rainy season for shootfly resistance. A total of 136 sweet sorghum advanced hybrids and 119 hybrid seed parents and multi location test entries (25) were evaluated for disease reaction (anthracnose and grain mold) in 2009 rainy season.

For shootfly resistance in 2008 postrainy season, compared to control CSH 22SS (22% dead hearts), eight elite hybrids showed 8 - 63% less shootfly dead hearts (ranging from 8 – 20% dead hearts) and seven among them showed 3 to 9% damage due to stem borer dead hearts (CSH 22SS 11%) and that recorded an aphid score 3 to 4 (CSH 22SS: 3). Among the advanced hybrids, 9 hybrids had 7 - 57% less shootfly dead hearts (range 11 – 23%) compared to control (CSH 22SS: 27%) and three among them recorded 5 to 10% damage due to stem borer (CSH 22SS: 12%) and an aphid score 3 to 4 (CSH 22SS: 3). Among the B-lines, 16 B-lines showed 5 - 94% less shootfly dead hearts (range 1 – 16%) compared to control (296B: 17%) and nine among them recorded 7 to 12% damage due to stem borer (296B: 13%) and five among them had an aphid score of 4 to 5 (296B: 6). Among the R-lines, 56 R-lines had 14 - 89% less shootfly dead hearts (range 3 – 27%) compared to control (296B: 31%) and 40 among them had stem borer damage of 2 to 10% (296B: 11%) and 19 among them recorded an aphid score of 3 to 4 (296B: 5).

For shootfly resistance in 2009 rainy season, 11 elite hybrids had 11 - 42% less shootfly dead hearts (ranging from 54 – 84% dead hearts) compared to control CSH 22SS (94% dead heats) and they recorded an aphid score of 4 to 6 (CSH 22SS: 6). From advanced hybrids group, 12 hybrids had 5 - 14% less shootfly dead hearts (range 80 – 89% dead hearts)) compared to control CSH 22SS (93% dead heats) and they recorded an aphid score 4 to 6 (CSH 22SS: 6). In the B-lines, 10 B-lines had 5 - 51% less shootfly dead hearts (range 43 – 83%) compared to control (ICSB 38: 88%) and they recorded an aphid score of 4 to 5 (ICSB 38: 5). In the R-lines group, 24 R-lines recorded 5 - 52% less shootfly dead hearts (range 44 – 88%) compared to control (SSV 84: 93%) and 15 among them had an aphid score of 3 to 4 (SSV 84: 4).

For anthracnose resistance, data on disease severity were recorded on a 1-9 scale (1 = 0 to <1% leaf area covered with hypersensitive lesions with yellow flecks – highly resistant   and 9 = 76-100% leaf area covered with coalescing necrotic lesions with acervuli –highly susceptible) on whole plant basis at the soft-dough stage. Grain mold severity was also recorded in these entries at physiological maturity on a 1-9 scale (1= 0 to <1% mold infection – highly resistant and 9= 76-100% molded grains on a panicle- highly susceptible). Of the 136 elite hybrids, 15 hybrids were found resistant (≤3.0 score) and 42 moderately resistant (score >3 to ≤5) to anthracnose compared to susceptible control H 112 with 9.0 score . Eleven hybrids among the 12 hybrids found resistant to anthracnose also exhibited moderate resistance to grain mold ranging severity score 2.0 to 5.0. Among the 119 elite B-lines, 70 B-lines were resistant to anthracnose (≤3.0 score) and among them 16 B-lines also showed resistance to grain mold ranging severity score 4.3 to 5.0. Among the 25 multi location test entries, 6 lines were resistant to anthracnose (≤3.0 score). Among them one variety/R-line –SPV 422 and hybrid ICSA 38 × ICSV 700 showed resistance to grain mold (PGMR scores 2.0 and 5.0). Sweet sorghum was cultivated in large area (>40 hectares) in farmers fields and on-farm productivity was enhanced (stalk yield 25 t ha^{-1}) by growing the sweet sorghum hybrid CSH 22 SS in 2009 rainy season.

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Output target 2010 5A. 8 Stay-green QTLs associated with improved fodder quality introgressed into elite sorghum hybrid parents and their potential utility assessed

Activity 5A. 8.1 Mapping and introgression of stay-green QTL into elite parental lines, and assessment of their effects on hybrid performance

Milestone 5B.8.1.1 Assessment of near-isogenic BC$_3$F$_3$ and BC$_4$F$_3$ stay-green QTL introgression lines completed in R16 and ISIAP Dorado backgrounds (CTH/SPD/VV/FRB/JK, 2010)

Achievement of Output Target:
75%
The work is almost completed. The materials have been generated and are now it their second year of evaluation, with a third year following on 2010-11. Controlled environment evaluation of a subset of the entries has been done twice to assess traits potentially leading to stay-green expression.

Participating Countries:
India

Participating Partners:
NRCS

Progress/Results:
Note: The ISIAP Dorado background has been substituted with a S35 background, more suitable to the target environment and also sweet sorghum entry.

Fifty-eight marker-aided stay-green QTL introgressed lines in the background of S35 and R16 were assessed in large and long PVC cylinders (2.0 m long and 25 cm diameter), with one plant in each cylinder, mimicking roughly the soil volume that sorghum plants would have at usual field planting densities. A fully irrigated control (weekly re-watering to 80% FC) and a terminal drought stress (last irrigation at 4 weeks after sowing) treatment were applied. These 58 stay-green introgession lines consisted of 26 in R16 background and 32 in S35 background, and the test also included local checks and parental lines. These lines were introgressed individually with 6 stay-green QTL (Stg1, Stg2, Stg3, Stg4, StgA, and StgB). The trial has been sown on 20th Oct in 2008. Re-saturation of the soil profile was performed between Nov 13 and 15th, by adding 3 liters of water to each cylinder to ensure that all lysimeters were saturated at the time of imposing the stress. Immediately after saturation, polyethylene beads were applied to the soil surface to prevent soil evaporation, at a rate of 600 mL, giving a layer of approximately 1.2 cm, sufficient to limit soil evaporation by about 80%. First weighing of the cylinders was taken on 19-20-21-22 November 08. Weighing was done following the same sequence, so that the interval between weighing was the same for all treatments and replications. Two treatments were applied: a water stress treatment and a fully irrigated control. Procedure for each of these treatments was as follows:

1. Water stress treatment: No water was added from the time of saturation, i.e. 15th Nov 08, except 1000 mL applied during grain filling on each of 02nd and 09th Jan 09. A total of five weighing were done for the water stress treatment, i.e. 21-22 Nov, 5-6 Dec, 19-20 Dec, 7-8 Jan, 19-20. Plants were physiologically mature at the time of the last weighing and thus were harvested soon after weighing. Plant parts were separated in leaf, stem, panicle and grain weights.

2. Well-watered treatment: Weighing of cylinders was done six times, on: 19-20 Nov 08, 3-4 Dec 08, 17-18 Dec 08, 5-6 Jan 09, 21-22 Jan 09, and 2-3 February. Plants were harvested soon after the last weighing. For genotypes maturing earlier, the head had been harvested before to avoid grain losses. However, all the stover biomass was harvested at same time. Leaf loss before harvest was minimum and was overlooked in the total leaf weights.

Special Project Funding:
ACIAR

Vincent Vadez, Tom Hash and Santosh Deshpande

Milestone 5B.8.1. Assessment of near-isogenic BC₃F₃ and BC₄F₃ stay-green QTL introgression lines completed in R16 and ISIAP Dorado backgrounds (CTH/SPD/VV/FRB/JK, 2010)

Achievement of Output Target:
75%

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Three-replicate trials of stay-green QTL introgression lines in the genetic background of highly-senescent rabi-adapted variety (and pollinator) R 16 and moderately senescent sweet-stalked variety (and sweet sorghum pollinator) S 35 were evaluated under rainfed and supplementally irrigated conditions at ICRISAT-Patancheru during the postrainy season of 2008-10. The trials were adversely affected by rust from neighboring sorghum germplasm plots, and several short-statured entries were badly damaged by feral pigs and/or 4-horned antelope. None-the-less, three superior entries in R16 background (all homozygous for well-expressed stay-green QTL *stgB* from donor parent B35) were identified. Initial results from earlier-generation evaluation of the R 16-background materials was published in Euphytica.

Special Project Funding:
Australian Centre for International Agriculture Research

CT Hash, SP Deshpande, V Vadez and FR Bidinger

Milestone 5B.8.1.2 Stay-green QTL mapping of E 36-1 confirmed based on phenotypic assessment of two F₆ RIL populations genotyped with DArT, SSR, and CISP-SNP markers (CTH/SS/SPD/VV, 2010)

Achievement of Output Target:
50%

Participating Countries:
United Kingdom; USA and India

Participating Partners:
University of Sheffield; Sheffield, UK; University of Georgia, Athens, Georgia, USA; Marathwada University, Parbhani, Maharashtra, India

Progress/Results:
A trial of 240 entries including 220 RILs from the cross N13 × E36-1, and repeated parental check entries, was conducted at ICRISAT-Patancheru during the postrainy season of 2009-10, under moderate terminal drought stress conditions and fully irrigated control conditions.

This trial is being repeated during the postrainy season of 2009-10. The RIL population has been skeleton mapped with about 60 SSR markers, and will now be genotyped with DArT markers to provide the required high density full-genome linkage map for use in subsequent QTL analysis. A second RIL population based on cross IS 9830 × E 36-1 is being prepared for SSR and DArT genotyping during 2010.

CT Hash, SP Deshpande, S Senthilvel and V Vadez

Milestone 5B.8.1.3 Stay-green QTL introgression sorghum lines based on donor parent E 36-1 available for phenotypic evaluation in two diverse genetic backgrounds (CTH/SPD, 2011)

No report provided

Milestone 5A.8.1.4: Initial evaluation of animal performance on near-isogenic hybrids differing in allelic composition at two stay-green QTLs completed (CTH/SPD/MB/BVSR, 2010)

No report provided

Output target 5A.9 Commercialization of sorghum grains and impact of improved germplasm enhanced

Activity 5A.9.1 Strengthen research and development partnerships, and technology exchange

Milestone 5A.9.1.1 Hybrid parents (>50) and other breeding materials (>100) supplied to NARS and their impact assessed (BVSR/sorghum team - annual)

Achievement of Output Target:
100%

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
Seed supplies: A total of 2443 seed samples of hybrid parents/breeding lines were sent to 21 countries. India received 1348 samples followed by Philippines (389 samples) and Mali (328 samples). Of the 1348 seed samples supplied in India, 540 were sent to public sector scientists, 715 to private sector scientists and the remaining 93 samples to farmers and NGOs/collaborators. Seed in bulk quantities (240 kg) of eight high-yielding/released cultivars and one sweet stalk hybrid were given to 60 farmers. Nucleus seed of ICSV 745 (2 kg), CSV 13 (3 kg) and MR 750 (2 kg) supplied to NARS. CSH 22SS (100kg), SSV 84 (100kg), 93046 (40kg), PVK 801(40kg), SPV 1616 (12 kg) were supplied for demonstration plots in Mahabubnagar District in Andhra Pradesh, India.

Other activities

Biofuel research collaboration: Under the IFAD-funded Biofuels project an on-farm breeding trial was conducted (discussed under **Milestone 5A.7.1.1**) and multilocation trials of hybrids, varieties and maintainer lines were conducted (discussed under **Milestone 5A.7.1.2**). Under European commission-funded Sweetfuel project, the drought-tolerant hybrids/ varieties (10) were supplied to UANL, Mexico. Efforts are underway to get material from ARC-GCI, South Africa and UANL, Mexico. A collaborative experiment with JIRCAS, Japan, on biological nitrification inhibition (BNI) capacity of sweet sorghum in vertisols is being conducted.

A trial on ratoonability of sweet sorghum genotypes is being conducted in collaboration with M/s Advanta Seeds Pvt Ltd to improve the harvesting window of raw material supply to distilleries. Nine promising sweet sorghum and grain sorghum genotypes were evaluated in a ratoonability trial during the 2009 rainy season. In the main crop, compared to trial mean sugar yield of 1.7 t ha^{-1}, two sweet sorghum hybrids ICSA 731 x ICSV 93046 (3.0 t ha^{-1}) and CSH 22SS (2.3 t ha^{-1}) and a sweet sorghum variety ICSV 93046 (2.3 t ha^{-1}) were significantly superior. They had reached a plant height of 3.2 to 3.5 m (mean: 3.0 m) and a Brix% of 18.0 to 19.3 (mean: 17.7).

Production of certified seed of sweet sorghum cultivars CSH 22 SS, ICSV 93046 and twenty promising sweet sorghum hybrids is being carried out in the postrainy season 2009. Information bulletin on sweet sorghum entitled "Sweet sorghum as a biofuel and strategies for its improvement" was published in collaboration with DSR.

Effect of sowing date on agronomic traits in sweet sorghum: A trial consisting of two varieties and six hybrids was evaluated in a 3 replicated RCBD sown on first of every month from May 2008 to April 2009. Each entry was planted in 4 rows of 4 m length. Data were collected on plant height, days to 50 % flowering; stalk yield, juice yield, sugar yield and bagasse yield. In each entry ten plants were crushed at flowering and at maturity. The ANOVA revealed significant interaction between genotypes and sowing date for all the traits. The sugar yield decreased from May to Dec sowings and then gradually increased. Sugar yield was highest in May-sown crop (3.7 t ha^{-1}), followed by June and March sowings (3.2 t ha^{-1}). Brix% was high in all the genotypes sown in July (18 %) followed by March (17.5 %) and August (16.5%) sowings. However, grain yield was maximum when the sowings were taken up in Nov (5.7 t ha^{-1}) followed by Dec (4.9 t ha^{-1}). The stalk yield was highest in the entries sown in May (82.6 t ha^{-1} at the flowering stage and 60 t ha^{-1} at maturity stage) followed by June-sown ones (70 t ha^{-1} at flowering stage and 60.9 t ha^{-1} at maturity stage). Juice volume was highest in the genotypes sown in the month of May (25 kl ha^{-1} at flowering and 22.7 kl ha^{-1} at maturity) followed by June-sown crop (23.9 kl ha^{-1} at flowering and 19.3 kl ha^{-1} at maturity). Plant height was highest in the genotypes sown in June (3.0 m) followed by May and July (each 2.9 m). Days to 50% flowering was delayed in November crop (107 days), followed by May (100 days) in the all genotypes and lowest days to 50% flowering was recorded in the Oct-sown crop (63 Days). The average stem girth was high in all the genotypes sown in month of May (23.3 mm), followed by March-sown crop (23.1 mm), while the lowest was observed in month of Nov (15.7 mm). The tested entries are found to be best for sugar yield, if sowing is taken up during the months of March, May, June and August, while crop sown in Oct, Nov and Dec recorded poor yields.

Monitoring the dynamics of total soluble solids: The Brix% (total soluble solids) was measured on 5th internodes in CSH 22SS and ICSV 93046 on alternate days from 5th day to 55th day after flowering during postrainy season 2008. In CSH 22SS, the Brix% gradually decreased from 11% (5 DAF) to 5.3 (26 DAF) and gradually increased to 12% by 42 DAF, then further declined (8.4% by 52 DAF). In ICSV 93046, the Brix% was in the range of 10.7 to 16.3 up to dough stage and decreased to 6.9% by 25 DAF and shortly increased to 10.5% by 53 DAF. The trend was not clear in both the genotypes. It needs to be repeated with large number of samples.

Sterile hybrids trial (SHT): Thirteen sweet sorghum male-sterile hybrids along with controls SSV 84 and CSH 22SS were evaluated to know the effect of selfing and open pollination during postrainy season 2008. The fertility restoration % among the hybrids ranged from 0 to 10% under selfing compared to that of 100% in controls. Six hybrids ICSA 749 x SPV 1411 (1.8 t ha^{-1}), ICSA 749 x ICSV 93046 (1.5 t ha^{-1}), ICSA 95 x AKSV 13 (1.4 t ha^{-1}), ICSA 38 x ICSV 93046 (1.4 t ha^{-1}), ICSA 502 x ICSV 93046 and ICSA 731 x ICSV 93046 (each 1.2 t ha^{-1}) were superior for sugar yield. The Brix% of the sterile hybrids was 120% less under open pollination compared to that under selfing (0.5 t ha^{-1} vs. 1.1 t ha^{-1}). Even in case of self fertile controls there was significant reduction under open pollination (by over 100%) compared to that under selfing.

Monitoring quantitative and qualitative losses due to delay in crushing: A trial was conducted to know the effect of delay of crushing by four days (96 hrs) of stalks harvested from irrigated and unirrigated (stopped irrigation after flowering) treatments in ICSV 93046, a sweet sorghum variety and CSH 22SS, a sweet sorghum hybrid. In the irrigated condition, the stalk weight of ICSV93046 declined by 10.4% after 1 day, 20.2% after 2 days, 24.3% after 3 days and 25.5% after 4 days of delay. In CSH 22SS, the reduction was 13.4%, 23.7%, 29.8% and 29.3% with 1, 2, 3 and 4 days delay in crushing. The Brix% increased from 13.1% to 14.6% in ICSV 93046 and from 10 to 17.2% in CSH 22SS in 96 hours. On an average the sugar yield declined by 20.2%, 15.9%, 26.4% and 43% due to delay in crushing by 1 day, 2 days, 3 days and 4 days. Under unirrigated condition, stalk weight reduced by 6.1% after 1 day, 12.6% after 2 days, 20.2% after 3 days of delay in crushing in ICSV 93046; 17.2% after 1 day, 29.7% after 2 days, 32% after 3 days of delayed crushing in CSH 22SS. Sugar yield declined by 31.3%, 9.9% and 5.4% in ICSV 93046 after 1 day, 2 days and 3 days of staling. Since the results were inconsistent in CSH 22SS, these need to be validated by further experimentation.

Assessment of internodal Brix% variation in sweet sorghum varieties and hybrids: An experiment was conducted to know internodal Brix% variation in four sweet sorghum hybrids (ICSA 52 x SPV 1411, ICSA 474 x SSV 74, ICSA 702 x SSV 74 and CSH 22SS) and five sweet sorghum varieties (SP 4511-2, SPV 422, SP 4511-3, RSSV 9 and SSV 84) during postrainy season 2008. In hybrids, mean Brix% varied from 14.8 to 15.6 in the first six internodes from bottom and gradually reduced to 10.7 by 10th internode. However, in the varieties Brix% increased from 16.6 in the first internode to 17.8 in 6th internode and gradually reduced to 11.8 at 10th internode.

Special Project Funding:
Nil

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Milestone 5A.9.1.2: Ten sorghum scientists trained biannually (BVSR/sorghum team—alternate year)

Achievement of Output Target:
100%
One bulletin each on Sweet sorghum and establishment and maintenance of decentralized crushing cum syrup making unit (DCU) published

Participating Countries:
Open to all countries

Participating Partners:
NARS and Private sector

Process/Results:
Eight researchers were trained on different aspects of sorghum breeding
- A Kola Lavakusa Rao from India worked as an intern on sweet sorghum evaluation from 18 May to 17 Sep 2009.
- Remolacia Mario Imperio from the Philippines was trained on seed multiplication and evaluation of sweet sorghum cultivars from 23 March to 22 April 2009.
- Richard Dar Dela Cruz from the Philippines was trained on seed multiplication and evaluation of sweet sorghum cultivars from 23 March to 22 April 2009.
- Valentin Corpuz Godoy from the Philippines was trained on Sweet Sorghum crop production and diseases, and Post harvest operations from 17 September to 15 October 2009.
- Odilon Villanueva Caraan from the Philippines was trained on Sweet Sorghum crop production and diseases, and Post harvest operations from 17 September to 15 October 2009.
- Lee Yong Hwa from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009
- Moon Youn Ho from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009
- Jong Rae from South Korea was trained on Sweet Sorghum Breeding for Bio-ethanol Production from 8 December to 11 December 2009

Special Project Funding:
ICRISAT-Pvt. sector Sorghum Hybrid Parents Research Consortium

Belum VS Reddy, A Ashok Kumar, P Srinivasa Rao and team

Pearl millet

Output target 5A.1 Genetically diverse, high-yielding and downy mildew (DM) resistant pearl millet parental lines of potential grain hybrids (at least 9 each of seed parents and restorer parents) developed annually during 2006-2011.

Activity 5A 1.1 Develop and characterize regionally adapted high-yielding and DM resistant hybrid parents

Milestone 5A.1.1.1 Diverse range of high-yielding and DM resistant seed parents and restorer parents developed (KNR/RB/RPT/RS, annual)

Achievement of Output Target:
100%
The target of nine each of A-lines and R-lines annually developed and designated for dissemination achieved.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Seed parents with high grain yield potential and downy mildew resistance are the backbone of a sound hybrid development program. Working in this direction, every year pearl millet team at ICRISAT-Patancheru attempts to develop and designate about 9 new male sterile lines (A-lines) in different *cytoplasmic* backgrounds for use by the public and private sector. In 2009, nine A-lines of diverse parentage and morphological characteristics, varying from 43 to 65 days for 50% flowering time, 65 to 160 cm plant height, 15 to 35cm for panicle length and 7.0 to 12.8 g of 1000-grain weight were developed. Of these, 4 A-lines were in A_1, 3 in A_4 and 2 in A_5 cytoplasmic background. The counterpart B-lines of these A-lines were highly resistant to at least two of the five diverse pathotypes of downy mildew ($\leq$10% disease incidence) under high disease pressure in greenhouse seedling inoculation test (> 95 % disease incidence in the susceptible check 7042S). Six B-lines were found resistant to all the five pathotypes, while three were found resistant to two of these pathotypes. More than 160 B-lines at the BC_1 to BC_{10} stages of backcrossing in different cytoplasmic backgrounds (55 A_1, 85 A_4 and 108 A_5 cytoplasm) were planted, of which 130 B-lines and the corresponding BC lines with 41 in A_1 cytoplasm, 67 in A_4 cytoplasm and 89 in A_5 cytoplasm were selected for further evaluation and conversion into A-lines.

An equally important program of restorer line development runs parallel to the seed parents program to develop diverse, DM resistant and high-yielding restorer lines. Working in this direction, nine restorer lines (R-lines) of diverse parentage and morphological characteristics varying from 51 to 66 days for time to 50% flower, 120 to 178 cm plant height, 12 to 31 cm panicle length and 6.0 to 11.0 g of 1000- grain weight were developed. All of these were highly resistant to at least two of the five diverse pathotypes with ICMR 09666 being resistant to all the five pathotypes, while four of these were highly resistant to four pathotypes, two were resistant to three pathotypes and two were resistant to two pathotypes under high disease pressure in the green house seedling inoculation test (100% disease incidence in the susceptible check 7042S). Five of these lines were restorers of the A_1 cytoplasm, and four were restorers of the A_4 cytoplasm.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

<div align="right">SK Gupta, KN Rai, RP Thakur and Rajan Sharma</div>

Output target 5A.2 More than 500 trait-specific and DM resistant improved breeding lines of pearl millet developed and disseminated alternate years (2006, 2008, 2010 and 2012) for use in breeding parental lines of grain hybrids

Activity 5A. 2.1 Develop a diverse range of high-yielding and DM resistant trait-specific breeding lines

Milestone 5A 2.1.1 Germplasm with large seed, high biomass yield, white grain color and large panicles identified and introgressed (KNR/RB/HDU/RPT/RS, 2009)

Achievement of Output Target:
Fully achieved

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl millet Improvement Project and its sub-centers

Progress/Results:
Introgression of traits of importance is continuously practiced to generate breeding materials with new variability. Working in this direction, about 132 large grain size seed parent progenies (F_5 onwards) were selected out of 479 planted during post rainy season 2009, for grain size and agronomic performance. Of these, about 57 entries had 1000-grain weight of more than 15g, of which 17 entries flowered in less than 55 days (check seed parent ICMB 00444 flowered in 49 days). In these selections, 4 progenies had 1000-grain weight of more than 20g. Three nurseries comprising of 177 advanced seed parent progenies (F_6 onward) selected for grain size and other agronomic traits were evaluated in 2009 rainy season, of which 66 progenies were selected based on agronomic performance and large seed size with 37 progenies flowering in 56-65 days (check seed parent ICMB 04888 flowered in 55 days). In seed parent breeding program, 474 advanced progenies (F_7-F_9/S_7) were selected on the basis of panicle length and other agronomic traits out of 1053 progenies, of which 57 progenies had panicle length of 31-40 cm; 24 progenies had panicle length of 41-50 cm and one progeny recorded panicle length of more than 50 cm (check ICMB 04777 recorded panicle length of 40 cm). In restorer breeding program 477 progenies (F_4-F_{11}/ S_9-S_{10}) developed using long panicled parental lines like RCB-2, ICMS 7704, and Zongo were evaluated in 5 nurseries, of which 103 were selected based on visual assessment for agronomic performance and long panicles. More than 500 long panicled progenies in F_3 were evaluated of which 267 were selected with 22 of them flowering in 41-45 days and 127 flowering in 46-50 days. Forty three advanced white-seeded progenies were evaluated of which 13 progenies were selected based on white seed color and agronomic performance. In an attempt to expand white-seeded material, about 202 newly developed F_1s were evaluated, of which 62 were selected for further advancement.

In the recent years, concept of forage pearl millet has been picking up fast considering its time of availability in summer season when no other forage is available in the fields. Working in this direction, four partially converted country-specific gene pools (Burkina Faso, Nigeria, Cameroon and Tanzania) were selfed and 77 plants with apparently high biomass potential were selected and re-evaluated in *rabi* 2008, of which 43 plants producing high biomass were selected from 20 progenies.

<div align="right">SK Gupta, KN Rai, HD Upadhyaya, RP Thakur and Rajan Sharma</div>

Milestone 5A.2.1.2 Genetically diverse trait-specific (eg. large seed, large panicle size, diverse maturity and height) advanced breeding lines developed and disseminated (KNR/RB/RPT/RS, 2006, 2008, 2010, 2012)

Achievement of Output Target:
70%
A large number and diverse range of trait-specific breeding lines have been developed which will be re-evaluated to identify those for 2010 scientists field day.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl millet Improvement Project and its sub-centers

Progress/Results:
Keeping into consideration the trait-specific requirements of different agro-regions, improved breeding lines are developed continuously in the hybrid breeding program. Besides grain yield potential, flowering time, DM resistance and overall agronomic performance are the prime criteria for selection and advancement of breeding material. Results of large-seeded and long-panicle trait-specific breeding lines have been reported above under milestone 5A.2.1.1.

Trait-specific seed parent progenies: About 450 breeding lines were evaluated in different trait-specific nurseries in rainy season of 2009. In the extra-early and early maturity group, 144 progenies were evaluated of which 35 were selected with 17 of them flowering in 41-45 days (the check seed parent 843B took 41 days to flower). About 70 thick paniced and 62 compact paniced progenies were evaluated, of which 19 thick paniced superior lines and about 27 agronomically good and very compact progenies were selected, respectively. Various other traits of importance were also selected for, like about 66 very dwarf progenies (45-80 cm) and about 74 F_6 bristled progenies were evaluated, of which 27 very dwarf and 27 bristled progenies were selected respectively. About 61 stay-green lines were evaluated of which 27 were selected with 4 progenies flowering in 51-55 days (check seed parent ICMB 89111 flowered in 51 days). In addition, 1780 progenies at various stages of inbreeding (F_3-F_{10}) and with a wide range of flowering (41-65 days) were also evaluated of which 685 were selected. These are yet to be classified in trait- specific groups.

Trait-specific restorer progenies: More than 1500 progenies under various trait–specific groups were evaluated for field performance in rainy season of 2009. In early and extra-early maturity group, 905 S_3-S_{13}/ F_5-F_8 progenies were evaluated of which 378 progenies were selected with 26 of these flowering in less than 45 days. In the high tillering group, 27 progenies were evaluated of which 12 were selected with 4 of them flowering in 41-50 days .In thick panicle group, 442 F_3 progenies were evaluated of which 185 were selected with 18 of them flowering in less than 45 days and 122 flowering in 46-55 days. We also evaluated a large number of lines for sources of other traits (panicle compactness, stay–green, lodging resistance and erect growth habit). In the compact panicles group, 139 S_2-S_{12}/ F_4-F_7 progenies were evaluated of which 66 were selected; in stay-green group 204 F_2-F_3/ S_7-S_{14} progenies were evaluated of which 67 were selected; in lodging resistance group 36 S_4- S_{11}/ F_5-F_{10} were evaluated of which 18 were selected; and in the erect-growth habit group, 21 S_5-S_{13}/ F_6-F_{10} progenies were evaluated of which 8 were selected. *Iniadi* plant type, characterized by large grains of dark grey color is preferred in Maharashtra. Thus, 89 *iniadi type* S_7/ F_7 progenies were evaluated of which 21 were selected. Progenies are also derived from inter crossing of improved populations for selecting trait-specific breeding lines; 137 F_6-F_9 progenies derived from intercrosses amongst various promising populations were evaluated , of which 50 trait-specific lines were selected.

<div align="right">SK Gupta, KN Rai, RP Thakur and Rajan Sharma</div>

Milestone 5A.2.1.3 An elite B-composite and an elite R-composite with resistance to multiple pathotypes of downy mildew populations developed (KNR/RB/RPT/RS, 2009)

Achievement of Output Target:
90%
Formation of R-composite is completed. Formation of B-composite is nearly completed with the final random mating to be done

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Eleven potential restorers highly resistant (≤10% disease incidence under high disease pressure in the greenhouse) to five diverse pathotypes (Banaskantha, Barmer, Jamnagar, Jodhpur and Jalna) and four potential restorers highly resistant to any four of these five pathotypes had undergone two cycles of random mating in 2008. Third and final random mating in this material was done in summer season of 2009, after which selected plants were bulked to finally develop Multiple DM Resistant Restorer Composite (MDMRRC). About 61 half-sibs derived

from MDMRRC were evaluated in rainy season of 2009 of which 23 progenies were selected based on agronomic performance that would be utilized for developing restorer lines with resistance to multiple pathotypes. About 100 rows of MDMRRC were planted in rainy season of 2009 from which about 325 promising plants were selected based on agronomic performance and desired plant type.

Nineteen potential seed parental lines with high levels of DM resistance to Banaskantha, Barmer, Jamnagar, Durgapura and Jalna pathotypes were finally selected from about 264 entries for intercrossing to constitute Multiple DM Resistant Maintainer Composite (MDMRBC). These selected lines were random mated in summer 2009, followed by second cycle of random mating in rainy season of 2009. The developed material will undergo third and final cycle of random mating in summer of 2010 to finally develop MDMRBC.

<div align="right">SK Gupta, KN Rai, RP Thakur and Rajan Sharma</div>

Output target 2009 5A.3 Morphological and molecular diversity of more than 150 elite inbred lines of pearl millet assessed and the relationship between diversity and yield heterosis demonstrated

Activity 5A 3.1 Evaluate parental lines, advanced breeding lines and their hybrids for grain yield, and morphological and molecular diversity

Milestone 5A.3.1.1 Designated seed parents and restorer lines characterized for DUS traits and molecular diversity (KNR/RB/RV, 2008)

Achievement of Output Target:
90%
Characterization and documentation of designated seed parents has been completed. Molecular and morphological data of designated restorer parents have been generated and analyzed. Preparation of the document is under way.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Morphological characterization of designated hybrid parents: Ninety-nine pairs of A-/B-lines, developed during 1981-2004 were evaluated for two seasons (post rainy season and rainy season, 2005) for 26 morphological traits using DUS descriptors, results of which have been summarized in 2009 issue of SAT Journal of Agricultural Research. The detail data have been documented, which will be available on ICRISAT's website.

More than 1700 pearl millet pollinators maintained in the ICRISAT Pearl Millet Pollinator Collection are designated as IPC (ICRISAT Pollinator Collection) numbers, in order of their development in the breeding program at ICRISAT. From this collection, 114 pollinators which are relatively more promising based on plant characteristics and diversity were evaluated in 2007 rainy season and 2008 post rainy season for 26 morphological traits using DUS descriptors. The parentage of these lines revealed that wide range of germplasm and improved lines has been utilized in the development of these lines. For instance, 19 R-lines were directly selected from the germplasm accessions, and 11 were selected directly from composites. In addition, 8 R-lines were derived from crosses that involved germplasm in their parentage and 17 lines had composites in their parentage. Thus, there were 55 pollinators that had some components of germplasm and /or composites in their parentage, indicating apparently substantial usage of germplasm/composites in the development of these parental lines. The remaining 59 parental lines were derived from crosses between elite inbred lines. Genotypes had significant differences for all the quantitative traits under study, which revealed presence of significant genetic variability among the pollinator lines. For instance, based on mean of both the seasons, plant height ranged from 56 to 201 cm, 50 % flowering ranged from 43 to 61 days, panicle length from 10 to 40 cm and 1000–grain weight from 5.7 to 14.0 g.

Frequency distribution of the 114 pollinators for 16 qualitative and quasi- qualitative characters revealed considerable variation for traits like anthocyanin pigmentation of first leaf, panicle exertion, panicle density, plant node pigmentation, panicle shape, seed shape and seed color. Majority of the lines (80%) were intermediate in their growth habit. Most of the pollinator lines were non-bristled. Only 15 lines had pubescent node and 8 had pubescent leaf sheath. Green color was most dominant for node (58%) and internode (98%) pigmentation, brown color being the next major trait in node and red in the internode. Majority of the lines had grey colored seeds (74%) followed by cream (17%) and deep grey colored (6%) seeds. Obovate seed shape (57%) was most dominant, followed by globular (39%) and only 3% lines were both elliptical and hexagonal in seed shape. About 74% of the lines had complete panicle exertion and 24% had incomplete exertion and 1 line had variable exertion. Semi-compact panicles were most common (43%), followed by compact (22%) and loose panicle (15%).

Variability in some of the pollinators was observed even across the two replications for some traits like anthocyanin pigmentation of seedlings, anther color, panicle exertion, panicle density, plant growth habit and plant node pigmentation. Eighteen pollinators had alternate phenotypes other than the predominant class for panicle density across both the seasons or in a single season .For instance, IPC 687 had compact panicles in rainy season but had loose panicles in dry season. Similarly, alternate phenotypes were present in 14 pollinator lines for anthocyanin pigmentation of seedlings, either across both the seasons or in a single season. For instance, alternate phenotypes for seedling pigmentation color were present in IPC 408 in both the seasons while IPC 906 had alternate phenotypes in rainy season only. Similarly, for panicle exertion, alternate phenotypes were present in IPC 1000 in both the seasons. This within-line variability seems to be due to the method of pollination used, where pollen from 10-15 plants was bulked for the maintenance of these pollinator lines. It is possible that other pollinator lines which have not shown such within-line variability in this study, might show it if tested with larger sample size, and perhaps in different environments. Therefore, there is every possibility that with larger number of plants for these pollinator parents, one can come across a few plants that expresses the alternate phenotype of these qualitative (or quasi-qualitative) traits, which otherwise should not be construed as a new phenotype or plant type at any given time. This information is being compiled in a document entitled "Characterization of ICRISAT-bred pollinator parents of pearl millet"

Molecular diversity

Genotyping of 99 B-lines and 150 R-lines with 40 markers (36 SSR and 4 EST) well distributed across all seven linkage groups was completed. The polymorphic information content (PIC) of these markers for B- lines ranged between 0.31 and 0.89 with a mean of 0.62, and for R- lines it ranged between 0.19 and 0.88 with a mean of 0.68. Preliminary investigations based on hierarchical cluster analysis following weighted neighborhood - joining method clustered all the B- lines into two major groups and all the R-lines into a single cluster. The draft paper reporting these results is under preparation.

Within-line variability

Six phenotypically diverse B-lines and six R-lines were assessed for within-line variability. Thirty two single-plant derived selfed progenies each from B-lines and R-lines were evaluated in a replicated trial in postrainy and rainy seasons of 2008 and data recorded for days to 50% flowering, plant height, panicle length, panicle diameter and 1000-grain weight. Significant differences were observed among the 6 B-lines and 6 R-lines for all the characters in both the seasons. Although wide range of variation was observed for most of the characters within all the B and R-lines, the genotypic coefficient of variation (GCV) for all the characters and for all the lines was very small. The differences among progenies within each inbred were significant for 28 out of 58 comparisons for 6 B-lines in both the seasons. Seasonal comparisons revealed that 18 cases of differences out of 30 were significant in post rainy season while 10 cases out of 28 had significant differences in rainy season.

The differences among progenies of ICMB 89111 were significant for all the characters in post rainy season followed by ICMB 97111 and ICMB 02111 for four characters (plant height, panicle length, panicle diameter and 1000-grain weight) each in post rainy season. In rainy season, ICMB 89111 had maximum number of significant differences for 3 characters (days to 50% flowering, plant height and panicle length) followed by ICMB 93333, -01222 and ICMB 02111 for 2 characters each. The differences among 843B progenies were non-significant in both the seasons, except for panicle length in post rainy season. All the 6 B-lines had significant differences among progenies for panicle length in post rainy season while maximum of 4 B-lines had significant differences for days to 50% flowering in post rainy season.

Among R-lines, 21 cases out of 60 had significant differences among progenies in both the seasons, while 12 cases in rainy season and 9 cases in post rainy had significant differences among progenies of the 6 R-lines. IPC 715 showed non- significant differences among its progenies for all the characters in both the seasons while IPC 909 had significant differences for all the five characters in the rainy season. Maximum significant differences among sub strains of R-lines were found for panicle diameter in rainy season, while most of the characters varied equally in post-rainy season. Maximum number of 4 R-lines had significant differences among progenies for panicle diameter in rainy season.

Three SSR marker loci (Xicmp3002, Xicmp3032 and Xicmp3080) exhibited heterozygosity in only ICMB 89111. The percentage of heterozygosity varied from 6% to 15% across 20 loci for eight DNA pools of ICMB 89111. Two loci (Xicmp3032 and Xicmp3080) mapping to pearl millet linkage group 1 showed heterozygosity in seven of eight DNA pools of ICMB 89111 and a third locus (Xicmp3002) revealed heterozygosity in only one DNA pool of ICMB 89111 (DNA pool 13-16). None of the other five B-lines exhibited significant SSR marker heterozygosity for the 20 markers studied in this experiment. In a similar way, only one out of six R-lines studied (IPC 422) exhibited marker heterozygosity. Among 8 DNA pools of IPC 422, three of them (DNA pools 5-8, 9-12 and 13-16) showed heterozygosity for the SSR marker Xpsmp2212 loci equivalent to 5% heterozygosity level when all loci were considered together and the other 5 pools were homozygous for this locus. The rest of the 19 loci appeared to be homozygous for the 8 DNA pools of all 6 R-lines.

SK Gupta, KN Rai and CT Hash

Milestone 5A.3.1.3 Two medium-maturity heterotic gene pools based on molecular marker diversity constituted (KNR/RB,/SC/RV, 2012)

Not yet initiated since the molecular diversity as a tool for identifying heterotic crosses is still to be established.

Activity 5A.4.2 Map-directed conventional backcrossing and marker-assisted backcrossing of DM resistance QTLs into parental lines of hybrids

Milestone 5A.4.2.2 Near-isogenic lines containing different DM resistance genes (QTL) developed (RPT/RS/CTH, 2010)

Achievement of Output Target:
50%
A large number of backcross progenies under the background of different B-lines containing several DMR
QTL from different donors have been screened over the past several years, but not even a single set of lines with confirmed QTL are available as yet to be classified/assessed as near-isogenic lines.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
About 640 progenies of advanced to BC_4F_1 and BC_3F_1s from elite parent (plant × plant crosses) with mapped DMR QTL including ICMB 90111-P6, P31-17, P7-3, P 1449-2-P1, PRLT 2/89-93 and 863B-P2 were screened against New Delhi (Sg 298), 98 progenies against Patancheru (Sg 409), 194 against Durgapura (Sg 212) and 205 against Ahmednagar (Sg 21) pathotypes. Fifty-six progenies were resistant (≤10% incidence) to Patancheru, 108 to New Delhi, 40 to Durgapura and 12 to Ahmednagar pathotype.

Rajan Sharma, RP Thakur and CT Hash

Milestone 5A.4.2.3 QTL with known effects against diverse pathotypes pyramided in 843B and other parental lines and their resistance levels determined (CTH/RPT/RS, 2010)

No report provided

Milestone 5A.4.2.5 Several different multiple-QTL introgression homozygotes available in genetic backgrounds of an elite restorer line and three diverse elite seed parents (CTH/TN/SS/RPT/RS, 2009)

No report provided

Output target 5A.5 Virulence changes in pearl millet DM pathogen populations determined (2009)

Activity 5A.5.1 Conduct field and laboratory studies to monitor the nature of virulence change in DM pathogen populations

Milestone 5A.5.1.2 Spatial and temporal virulence pattern of downy mildew pathogens assessed through virulence nursery and on-farm survey results (RPT/KNR/RB/CTH, 2009)

Achievement of Output Target:
100%
Virulence change in downy mildew pathogen, sclerospora graminocola, is an ongoing process largely influenced by changes in cultivars and weather variables. Therefore, this has to be continuously monitored through on-farm disease survey and multilocation virulence nursery. The new isolates are collected and characterized using differential hosts and molecular markers to identify new virulences. It is planned to be reported again in 2011 and subsequently every 3-5 years.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Seed Companies

Progress/Results:
Isolates of Sclerospora graminicola, the pearl millet downy mildew (DM) pathogen, collected from highly susceptible pearl millet hybrids during on-farm surveys in different states of India are characterized for pathogenic variation to monitor virulence change in the pathogen population. Highly virulent isolates thus identified from different states are used for screening germplasm and breeding lines for identifying new sources of resistance and developing DM-resistant hybrid parental lines and hybrids.

Virulence diversity was studied in S. graminicola populations (54 isolates) collected from nine Indian states (Andhra Pradesh- 5; Maharashtra- 3; Karnataka- 1; Rajasthan- 16; Gujarat- 5; New Delhi- 1; Haryana- 1; Uttar Pradesh-21 and Tamil Nadu-1) during 1992-2008. Pathogenic variation in the S. graminicola isolates was studied by their reaction on seven host differential lines (P 7-4, P310-17, 700651, 7042R, 852B, IP 18292 and IP 18293) in the greenhouse. For this, pot-grown seedlings of pearl millet lines were spray-inoculated at the coleoptile stage with sporangial suspensions of the test isolates. The inoculated seedlings were incubated at 20ºC and >90% RH for 20 h, and then transferred to a greenhouse bench at 25 ºC under misting (leaf wetness) for disease development. Downy mildew incidence was recorded 14 days after inoculation as percent infected plants. Quantitative differences in virulence of the isolates were assessed by calculating virulence index (disease incidence × latent period^{-1}).

Significant variation was observed for downy mildew incidence, latent period and virulence index among the test isolates. Based on their reaction type on host differentials, 54 isolates formed 20 pathogenic groups. Group 1 comprising 20 isolates was most virulent and the isolates belonging to this group were virulent on all the seven differentials. Group 19 represented by isolate Sg 468 (from Rajasthan) was the least virulent and could not cause >10% incidence in any of the seven differentials. A dendrogram (generated by the average linkage cluster analysis) of virulence index clustered the 54 isolates into five major groups. Based on virulence index, group I again appeared as the most virulent group comprising 7 isolates (3 from Rajasthan, 2 from Uttar Pradesh and 1 each from Gujarat and Andhra Pradesh) with >14 mean virulence index across differentials.

Thirty-seven SSR primers developed for genetic diversity studies in sorghum downy mildew pathogen (Peronosclerospora sorghi) were used to assess allelic diversity in S. graminicola. PCR was carried out to amplify SSR loci using DNA of the 54 isolates of S. graminicola and one isolate of P. sorghi. Of the 37 SSRs used to study allelic variation, only 20 could amplify reproducible fragments in the isolates tested. However, none of them was polymorphic, hence could not detect allelic variation/genetic diversity in the S. graminicola isolates. Therefore, there is a need to develop SSR markers specifically for S. graminicola for genetic diversity studies.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

<div align="right">RP Thakur, KN Rai, Rajan Sharma and CT Hash</div>

Output target 2009 5A.6 At least two improved populations and experimental hybrids of pearl millet with high forage yield potential developed

Activity 5A 6.1 Develop and evaluate improved open-pollinated varieties and hybrids for their forage yield potential

Milestone 5A.6.1.1 Additional germplasm sources with high biomass yield identified (KNR/RB/HDU/MB, 2009)

Achievement of Output Target:
100%
Ten germplasm accessions have been identified with higher dry biomass yield at 80 days after sowing in comparison to the control hybrid of Sorghum Sudan Grass hybrid "Jumbo", with three of them yielding 10% higher dry fodder yield over the control.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
In the recent years, concept of forage pearl millet has been picking up fast considering its time of availability in summer season when no other forage is available in the fields. This has necessitated exploiting germplasm accessions of diverse origin with high biomass yield. Fifty two new germplasm accessions with high biomass potential selected from a characterization block of the Genetic Resources Unit in 2007 were evaluated in rainy season of 2008 and 27 accessions with high biomass potential were selected for further evaluation. These 27 accessions were evaluated in summer season of 2009, of which 10 accessions (IP 6140, -6202, -6410, -6494, -11627, -12898, -14724, -15535, -17360, and IP 19415) gave more than 9 tons of dry biomass ha^{-1} at 80 days of sowing in comparison to the control Sorghum Sudan Grass hybrid "Jumbo" which yielded about 8.9 tons of dry biomass ha^{-1}. Amongst them, IP 6202, - 12898 and IP 15535 gave 10% higher dry fodder yield over the Sorghum Sudan Grass hybrid "Jumbo".

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, SK Gupta, HD Upadhyaya and M Blummel

Milestone 5A 6.1.3 Diverse seed parents with high forage yield potential developed and characterized (KNR/RB/MB, 2012)

Achievement of Output Target:
40%
Promising lines have been identified for further evaluation and utilization in hybridization program to develop forage seed parents.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
About 27 seed parent progenies (S_9-S_{10}), bred initially with an objective to develop seed parents of grain hybrids but having high biomass, were evaluated during the 2009 rainy season, of which 14 lines were selected. Of these, 8 progenies flowered in 51-60 days, while 6 progenies flowered in more than 61 days (Check ICMB 00999 flowered in 59 days). Conversion of some of these lines into A-lines and their hybridization *inter se* to further enhance the biomass yield potential will be initiated during 2010 concurrent to their further evaluation for performance *per se*.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, SK Gupta and M Blummel

Output target 2009 5A.8 Pearl millet technology exchange, capacity building and impact assessment undertaken and documented

Activity 5A 8.1: Enhance technology exchange and partnership building, and assess its impact

Milestone 5A.8.1.1: Seed of hybrid parents and breeding lines multiplied and distributed (KNR/RB, annual)

Achievement of Output Target:
100%. All the hybrid parents and breeding lines have been multiplied and supplied as per the seed request.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl millet Improvement Project and its sub-centers

Progress/Results:
Breeder seed production of A/B lines (ICMA/B 89111, -97111) was carried out to support NARS partners. About 600 kg breeder seed of A-/B- pairs and of ICTP 8203 was produced for supply to NARS collaborators in India.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

SK Gupta and KN Rai

Milestone 5A.8.1.2 ICRISAT's research partnerships with NARS, networks and regional for a strengthened (KNR/CLLG/pearl millet team, annual)

Achievement of Output Target:
It is a continuing effort, based on partners interest and opportunities for collaboration.

Participating Countries:
India

Participating Partners:
All India Coordinated Pearl millet Improvement Project and its sub-centers

Progress/Results:
Partnership with AICPMIP was further strengthened, leading to its sub-centers conducting HOPE project-related trials (though at small scale) and HarvestPlus trials (at large scale) even while the funding from these projects were not available to AICPMIP (and to its sub-centers) involved in this research. Negotiations were done with AICPMIP coordinator and OP Yadav (CAZRI) to bring the latter on board as co-editor of the book Pearl Millet Research and Development (under preparation). Partnership with ICBA was strengthened for increasing the popularity of pearl millet in the Middle East and Central Asia, and provided support to Adriana Seed Company for popularization of pearl millet in Brazil. Participation of Consortium Seed Companies was increased in HarvestPlus research. Millet breeders of Junagarh Agric. University and Nirmal Seed Company were motivated to participate in ICRISAT-coordinated survey of rabi-season pearl millet cultivation in Gujarat and Maharashtra, results of which were published in SAT journal of Agricultural Research.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

<div align="right">KN Rai, SK Gupta and CLL Gowda</div>

Milestone 5A 8.1.3 International Pearl Millet Training Course (2009) and Field Day (2006, 2008, 2010, 2012) conducted (KNR/CLL/pearl millet team)

Achievement of Output Target:
Yet to find support

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Communicated with FAO for funding support to this course for 2010, with no success. It will likely be held in 2011 if funds are available. Scientists Field Day will be held as per the schedule.

Special Project Funding:
None

<div align="right">KN Rai, SK Gupta and CLL Gowda</div>

Milestone 5A 8.1.4: Technical information and public awareness documents developed and disseminated (KNR/CLLG/pearl millet team, annual)

Achievement of Output Target (%):
100%
The intended documents were published.

Participating Countries:
India

Participating Partners:
AICPMIP

Progress/Results:
Continuing efforts with AICPMIP led to two joint publications: one on Pearl Millet Cultivars: Seeds of choice (updated version of an earlier document), and another one on Trait-Specific Germplasm Sources.

Special Project Funding:
None

<div align="right">KN Rai</div>

Pigeonpea

Output target 2006-2009 5A.1 About 15 high-yielding pigeonpea hybrids made available for cultivation in different environments

Activity 5A.1.1 Development of widely adapted high-yielding hybrids for different environments

Milestone 5A.1.1.1 At least 100 new hybrid combinations evaluated to identify new fertility restorers/male sterility maintainers (KBS/KML, 2006-09)

Achievement of Output Target:
100%
More than 140 hybrids in extra-short, short and medium-maturity groups were evaluated and more than 70 new restorers and 12 new maintainers have been identified so far. We have made available 17 pigeonpea hybrids to various private companies and NARS partners.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
During rainy season 2008, a total of 43 hybrids in extra-short, short and medium maturity duration were evaluated for identification of new fertility restorers and male sterility maintainers in five trials with two replications at Patancheru. All the trials were severely damaged first by water-logging and then by *Maruca* and pod-sucking bugs. These trials could not be analyzed statistically due to excessive plant loss due to water-logging. However, the fertility restoration data were recorded. Out of 43 hybrids, 28 were fertile (90-100% fertility restoration), four (ICPH 2460, ICPH 3313, ICPH 3629, ICPH 3171) maintained male-sterility (pollen sterility >80%) and 11 segregated for male fertility and sterility (21-89% fertility restoration). For development of new A- lines, single plant selections were made in the F1s of the four hybrids listed above for pollen sterility, plant type and important yield contributing traits like number of primary and secondary branches were carried out. These plants were backcrossed on single plant basis with their respective recurrent parent on single plant basis. In this maturity group, 29 new restorers were also identified on the basis of their fertility restoration in the hybrids. A total of 75 R- lines identified during previous and current seasons were grown under nylon nets. These lines were selfed and will be tested again for their fertility restoration in different cross combination during 2009. These lines will also be evaluated for *Fusarium* wilt, sterility mosaic (in disease screening nursery) and *Phytophthora* blight (field screening) resistance. Hence, in the past four years, more than 140 A_4-based hybrids were evaluated for male fertility restorers and maintainers. Currently, for A_4 system, we have 75 fertility restorers (with more than 90% fertility restoration), and 12 maintainers.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India
<div align="right">KB Saxena and RK Srivastava</div>

Milestone 5A.1.1.4 Elite pigeonpea hybrids evaluated for their resistance to major insects and diseases (HCS/SP/ KBS, 2009)

Achievement of Output Target:
75%
20 promising hybrids and their parents have been evaluated for pod borer resistance.

Participating Countries:
India

Participating Partners:
Indian Institute of Pulses Research

Progress/Results:
Relative susceptibility of short-duration pigeonpea hybrids and their parents to *Helicoverpa armigera*: Ten short-duration hybrids, two pairs of maintainer and male-sterile lines (ICPB & A 2039 and ICPB & A 2089) lines, and 10 restorer lines along with resistant (ICPL 88039) and susceptible (ICPL87) checks were evaluated for resistance to pod borer, *H. armigera* under field conditions. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage and recovery, overall resistance scores, pod damage, and grain yield. Pod borer damage in the first flush was very high (damage rating 5.5 to 9.0). Moderate levels of recovery resistance (ability to recover from damage by the pod borer and the pod damage in the second flush) were observed in ICPH 2363, ICPH 2429, ICPH 2433, ICPH 2460, and ICPR 2431 (DR scores 4.5 to 6.5). Pod damage was <35% in ICPB 2089, ICPR 2431, ICPR 2433, and ICPL 88039 in the second flush, both in the tagged inflorescences as well as in the samples collected at random. Grain yield was >0.5 t ha^{-1} in ICPH 2363, ICPH 2429, ICPH 2431, ICPH 2433, ICPH 2438, ICPH 2460, ICPR 2363, and ICPR 2433, compared to 0.46 t ha^{-1} for ICPR 88034 and 0.40 t ha^{-1} for ICPL 88039.

Relative susceptibility of medium-duration pigeonpea hybrids and their parents to *Helicoverpa armigera*: Ten medium-duration hybrids, three pairs of maintainer and male-sterile lines (ICPB & A 2043 and ICPB & A 2047, ICPB & A 2092) lines, and 10 restorer lines along with resistant (ICPL 332) and susceptible (ICPL 87119) checks were evaluated for resistance to pod borer, *H. armigera* under field conditions. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage and recovery, overall resistance scores, pod damage, and grain yield. Pod borer damage in the first flush was very high (damage rating 6.0 to 9.0). Moderate levels of recovery resistance (ability to recover from damage by the pod borer and the pod damage in the second flush) were observed in ICPH 3671, ICPH 2673, ICPH 2740, ICPH 3464, ICPL 3472, ICPB 2043, and ICPR 2673 (DR scores 4.0 to 5.5 compared to 7.0 in ICPL 332, 5.0 in ICPL 8863, and 7.5 in ICPL 87119). Pod damage was <30% in ICPH 2673, ICPH 3359, ICPH 3491, ICPH 3762, ICPB 2047, and ICPR 2673 compared to 31.48% damage in ICPL 332, and 48.95% in ICPL 87119. Grain yield was >1.0 t ha^{-1} in ICPH 2673 and ICPH 3472 compared to 0.5 t ha^{-1} of ICPL 332 and 0.2 t ha^{-1} of ICPL 87119.

Special Project Funding:
Tropical legumes II, Seed Consortium
<div align="right">HC Sharma, KB Saxena and R Srivastava</div>

Output target 5A.2 Genetically diverse pigeonpea hybrid parents (about 5-10 A lines and 10-15 R lines) with resistance to major biotic stresses developed (2009).

Activity 5A.2.1 Development of high-yielding pigeonpea hybrid parents with resistance to major biotic stresses.

Milestone 5A.2.1.1 At least six A_4 male-sterile and 15 fertility restorer lines with resistance to wilt and sterility mosaic disease developed (KBS/KML/SP, 2007)

Achievement of Output Target:
100%
Pigeonpea group has developed seven A-/B- lines and 55 R- lines with resistance to Fusarium wilt and sterility mosaic diseases.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector; NARES from ESA, Myanmar

Progress and results:

A_4-based male sterile lines and fertility restorers are being bred at ICRISAT, Patancheru. The male sterility segregation and stability of the A_4-based CMS lines have been quite encouraging. From the restorer breeding program, we have identified good number of restorers with high degree of fertility restoration and resistance to wilt and sterility mosaic diseases. During rainy season 2008, a total of seven A/B lines in BC_4– BC_{11} generations were scored for male sterility and screened in wilt and sterility mosaic disease sick nursery at Patancheru. Of these, two belonged to the short-maturity group and five to medium-maturity group. In short-maturity group, ICPA 2039 was in BC_{11} generation with 100% male sterility, whereas ICPA 2089 was in BC_5 generation with 95% male sterile sergeants. In ICPA 2089, single plant selections are being carried out to increase the frequency of male sterile plants. In medium-maturity group, a total of five (ICPA 2092, ICPA 2047, ICPA 2046, ICPA 2043, ICPA 2078) CMS lines in BC_4 to BC_{11} generations are being developed. Out of these, ICPA 2043 (female line of the launched hybrid ICPH 2671) was in BC_6 generation, ICPA 2046 and ICPA 2047 were in BC_5 generation, and ICPA 2092 and ICPA 2078 were in BC_4 generation. All these five lines were screened for *Fusarium* wilt and sterility mosaic diseases for three seasons (2006/07, 2007/08 and 2008/09), and were found to be resistant to both the diseases (mean disease score $\leq$10% on 1-9 scale).

In order to develop A_4-system restorer lines with combined resistance to *Fusarium* wilt and sterility mosaic diseases, a total of 353 restorer lines (on the basis of 2006/07 and 2007/08 data) were screened for wilt and sterility mosaic disease resistance during 2008. Of these, 191 belonged to short-maturity group, and 162 to medium-maturity group. In short-maturity group, no line was found resistant to both wilt and sterility mosaic diseases. In medium-maturity group a total of 55 R-lines recorded resistance to both *Fusarium* wilt and sterility mosaic diseases. In the light of emerging threat of *Phytophthora* blight, these lines will also be field screened for this disease, and fertility restoration will be tested in different cross combinations.

Milestone 5A.2.1.2 At least six promising maintainers of A_4 cytoplasm improved for agronomic traits (seed and pod size and disease resistance) through backcrossing (KBS/KML, 2009).

Achievement of Output Target:
85%
A total of seven maintainers are being improved for seed and pod size. Selection for high disease resistance is under progress.

Participating Countries:
India

Participant Partners:
Indian NARS and Private Sector

Progress/Results:

During 2008 rainy season, a total of seven maintainers (and their respective CMS lines) are being improved for seed size, pod length and width, and resistance to *Fusarium* wilt, and sterility mosaic diseases. Of these, two pairs of lines (ICPA/B 2042 and ICPA/B 2050) were in BC_5 generation, another two pairs (ICPA/B 2078 and ICPA/B 2098) in BC_4 generation, ICPA/B 2166 was in BC_2 generation, and ICPA/B 2188 and ICPA/B 2189 in BC_1 generation. Single plant selections and backcrossing were done for higher 100-seed weight, pod length and pod width in these seven A/B lines. These lines are being generation advanced during the rainy season 2009/10, and a subset will be grown in the *Fusarium* wilt and sterility mosaic disease resistant screening nursery.

In addition, during 2008 rainy season a total of 50 maintainer lines were screened for *Fusarium* wilt and sterility mosaic disease resistance. Data were also recorded on 100-seed mass, seeds pod^{-1}, days to flower, days to maturity, grain yield and other important agronomic traits. Out of these, a total of eight maintainer lines had resistance to both *Fusarium* wilt and sterility mosaic diseases. New breeding populations are also being developed. During 2008 rainy season, a total of 50 F_1s of the B × B crosses were grown. Due to severe *Phytophthira* blight and *Maurca* attack only 18 F_1s were selected for generation advancement during 2009 rainy season.

Output target 2009 5A.3 Pigeonpea hybrid parents (25-30 A-lines and 50-55 R-lines) characterized for important agronomic traits and molecular diversity

Activity 5A.3.1 Assessing the agronomic and molecular diversity of pigeonpea hybrid parental lines

Milestone 5A.3.1.1 A/B- and R- lines characterized for important agronomic traits (KBS/KML/HCS/SP, 2008)
Reported under Output Target 2009 5.1.2 PP

Milestone 5A.3.1.2 Available male sterile (A/B) and fertility restorer (R) lines characterized using molecular markers (RKV/ KML/ KBS/ DAH, 2009).
Reported under Output Target 2009 5.1.2 PP

Output target 2009 5A.4 Seed production technology for pigeonpea hybrids and their parents improved

Activity 5A.4.1 Developing an efficient seed production technology for pigeonpea hybrids and their parents.

Milestone 5A.4.1.1 Improved seed production technology for pigeonpea hybrids and their parents developed (KBS/KML, 2009)

Achievement of Output Target:
75%

Although the seed production technology has been developed for a few locations in south and central India, a few location-specific problems still need to be addressed.

Participating Countries:
India

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
Recommending correct isolation distance, row-ratio and appropriate agronomy is central to an efficient hybrid seed production technology. During 2008 rainy season an experiment was conducted to understand the affect of spacing, row-ratio, and frequency of irrigation on male-sterile (AxB) and hybrid (AxR) seed production. The data were recorded for plant height, days to flower and maturity, total biomass, stem diameter, number of productive branches, number of pods and seeds per plant. The following treatments for ICPH 2671 were studied. Two row-ratios each for A-line and hybrid seed production (4A:1B, 4A:1R and 3A:1B, 3A:1R) were studied for red and black soils. For both black and red soils, effect of eight spacing (T1 – 75 cm x 30 cm (control), T2 – 75 cm x 50 cm, T3 – 75 cm x 75 cm, T4 – 75 cm x 100 cm, T5 – 150 cm x 30 cm, T6 – 150 cm x 50 cm, T7 – 150 cm x 75 cm, T8 – 150 cm x 100 cm) and two irrigation frequencies (F1 – every 14-day, F2 – every 18 days) were studied. Initial results for red soil indicate that 150 cm x 75 cm in 4:1 ratio (for AxR) with every 14 days irrigation provided the highest number of productive branches plant^{-1} (101), number of pods plant^{-1} (1,103), the second highest in main stem diameter at harvest (3.6 cm) and biomass (2.5 kg plant^{-1}) as against the 3:1 row ratio treatments. For black soil, two weeks of irrigation frequency on 3A:1R row ratio for 150 cm x 50 cm produced the highest number of pods (875) and weight of biomass (1.1 kg plant^{-1}). For irrigation frequency of two weeks for 4:1 ratio, 150 cm x 75 cm provided the highest number of pods (874) and diameter of main stem at harvest (2.6 cm). From the above results, it can be provisionally concluded that planting distance of 150 cm x 75 cm at 4:1 ratio irrigated every two weeks can give highest grain yield for hybrid (AxR) seed production. However, more studies will be needed to find out more appropriate row ratio and spacing for parental line and hybrid seed production.

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Output target 2010 5.A.5 Efficiency of hybrid pigeonpea breeding improved through strategic research

Activity 5A.5.1 Conduct strategic research to improve the efficiency of hybrid breeding

Milestone 5A.5.1.3 New sources of cytoplasm identified and diverse CMS systems developed (KBS/NM/KML, 2010)

Achievement of Output Target:
60%
Diversification of cytoplasmic base of hybrid parental lines is in progress. We have materials in BC$_3$-E15 stage.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
A new source of CMS: *Cajanus platycarpus* was crossed with *C. cajan*. A series of backcrosses were carried out using *C. cajan* as the recurrent parent. A selection was made in BC$_2$ progeny and called BC$_2$F$_1$-E line. All the plants in this line had low fertility which ranged from 15 to 48 %. Crosses were made between BC$_2$F$_1$-E plants and cultivar Asha, ICPL 85010, ICP 1444, UPAS 120 and *C. platycarpus* accession ICPW 68 and percent pod set ranged from 5 to 25 %. Pollen fertility in plants from the cross BC$_2$F$_1$ and ICPL 85010 did not exceed 16 %. Crosses between BC$_3$-E15 progeny with low fertility, and cultivar ICPL 85010 gave rise to 7 % pod set. Eighteen plants were grown, their anther morphology studied and pollen fertility checked. Most of the anthers were sepalous, transparent and devoid of a regular anther cavity and absence of pollen grains. Some of the anthers had a miniature anther cavity with a few pollen grains. Such anthers did not dehisce. Upon closer study, it was observed that these anther cavities lacked the line of dehiscence and had thick anther wall, which prevented the dehiscence of anthers and release of pollen grains. Since dehiscence did not take place, anther sacs were forcefully ruptured by squashing the anthers, and self pollinations were carried out. In spite of self pollinations, none of the plants set seeds. Cross between BC$_3$-E15 and ICPL 87119 (Asha) gave rise to an average of 21% pod set. A total of 8 plants were grown in the glasshouse. Pollen fertility in the plants ranged from 0 to 54 %. It was possible to get pods from self pollinations. Cross between BC$_3$-E15 and ICP 88014 gave rise to 19 % pod set. Hybrids were fertile and pollen fertility in these plants ranged from 18 to 69 %, except for one plant which had 100 % sterile grains, all the other plants set pods from self pollinations. Cross with ICP 1444 gave rise to only fertile plants and pollen fertility in the plants ranged from 14 to 49 %. Cross with *C. platycarpus* ICPW 68 gave rise to 1.0 % pod set. Pollen fertility in the eight hybrids ranged from 0.0 to 44%. The results show that cultivar 85010 is the maintainer of CMS trait and the other cultivars show the traits of restorers. CMS is being reported for the first time with *C. platycarpus* cytoplasm.

A$_5$ cytoplasm (cultivated pigeonpea cytoplasm derived from the cross *C. cajan* x *C. acutifolius*): Twenty five lines were selected in 2009 which had different percentage of male sterile plants ranging from 0 to 87 %. Two lines which had more than 60 % of the plants with 100 % sterility were selected to be crossed with a range of genetically diverse varieties to identify good maintainers of male sterility. So far, fertile siblings have been found to be the best maintainers of male sterility. The crossing experiment should be able to identify some more maintainers.

KB Saxena, N Mallikarjuna and RK Srivastava

Output target 2011 5A.6 Trait-based breeding populations developed for selecting elite hybrid pigeonpea parental lines

Activity 5A.6.1 Development of trait specific (diverse maturity, disease resistance, seed and pod size) breeding populations for selecting new maintainers and restorers.

Milestone 5A.6.1.1 For each trait, about 10-12 genetically diverse lines will be identified and crossed in a half-diallel mating scheme to generate B and R breeding populations for selection (KBS/RKS/SP, 2011)

Achievement of Output Target:
80%
We are developing B-and R- lines with resistance/tolerance to pod borer, wilt and sterility mosaic diseases

Participating Countries:
India

Participating Partners:
None

Progress/Results:
In order to diversify the genetic background of the B- lines, a total of 18 F_2 populations are being grown during 2009 rainy season. These crosses were made using B- lines of A_4 cytoplasm belonging to early (DT x DT -3 crosses, NDT x DT- 6 crosses) and medium (NDT x NDT- 9 crosses) maturity groups. The F_2 populations are being grown in wilt-free plots. In early-maturity group, a total of 800 plants were grown, while in medium maturity a total of 840 plants were grown. Single plants selection are being done for diversity in various agronomic traits such as days to flower, maturity, 100-seed weight, number of pods, seeds pod^{-1}, seed coat color etc. This season was marked by unusual patter of rainfall. Initial drought was followed by continuous heavy rains, leading to severe plant mortality due to water-logging and *Phytophthora* blight. These selected lines are being grown in net to prevent outcrossing and for generation advance.

To diversify the genetic base of R- lines, a total of 101 RxR F_2 populations were grown during 2009 rainy season. These F_2s were generated from crosses made in a diallel mating design (resistant x resistant for both wilt and sterility mosaic diseases) from 15 elite wilt and sterility mosaic resistant R- lines of A_4 cytoplasm. Of these, 65 F_2s populations belonged to early maturity group while 36 F_2 populations belonged to the medium maturity group. These were planted in wilt-free plot, and under net to advance the generation.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India
                                        KB Saxena, RK Srivastava, S Pande, HC Sharma and Mamta Sharma

Output target 2010 5A.7 Hybrid pigeonpea technology exchange, capacity building of partners and documentation

Activity 5A.7.1 Exchange improved technologies and new knowledge with ARIs, NARS, NGOs, private sector, and farmers' groups

Milestone 5A.7.1.1 ICRISAT partnerships with NARS and Hybrid Parents Research Consortium Partners strengthened (KBS/CLLG/SP, annual)

Achievement of Output Target:
100%

Participating Countries:
China, India, Myanmar

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
ICRISAT has been engaged in the process of constant strengthening of its partnership with NARS of India, Myanmar, China, and members of the Pigeonpea Hybrid Parents Research Consortium (PHPRC). Through a series of meetings, field visits and informal talks, the partnership is further strengthened. During 2008/09 cropping season, scientists and pigeonpea breeding staff monitored multi-location trials and breeding materials planted at various locations by consortium partners. This includes Pioneer Overseas Corporation, Nath Biogene, Mahyco, Krishidhan Seeds, and Zuari Seeds. Some consortium partners and public seed company representatives who visited ICRISAT were from Mahyco, Krishidhan Seeds, JK Seeds, and National Seeds Corporation to monitor trials and learn about parental line (AxB) and hybrid seed (AxR) production technology. Scientists and staff from these companies interacted with ICRISAT scientists and had fruitful discussions about hybrid pigeonpea research and seed production technology.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India
                                                    KB Saxena, CLL Gowda and RK Srivastava

Milestone 5A.7.1.2 Seeds of elite parental lines, and hybrids multiplied and distributed to NARS and seed companies (KBS, annual)

Achievement of Output Target:
100%
All seed requests were met

Participating Countries:
India, Kenya, Myanmar, Nepal, Tanzania, USA

Participating Partners:
Indian NARS (Public and Private Sector), NARES from ESA, Myanmar

Progress/Results:
During 2008 a total of 1091 seed samples weighing 360 kg were supplied to 16 private seed companies under Standard Material Transfer Agreement (SMTA). These include 413 A/B lines (202 kg each of A- line and 53 kg of B- line), 567 R-lines (83 kg) and 70 hybrid samples (23 kg). In addition 41 hybrid trials in short and medium-duration maturities were also supplied to 12 seed companies for evaluation. The states covered were Andhra Pradesh, Chattisgarh, Delhi, Gujarat, Harayana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Orissa, Tamil Nadu, Uttar Pradesh, and Uttaranchal.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India
KB Saxena and RK Srivastava

Milestone 5A.7.1.4 Capacity of NARS and seed sector scientists/technicians in hybrid breeding strengthened (KBS/KML, annual)

Achievement of Output Target:
100%.

Participating Countries:
China, India, Myanmar

Participating Partners:
Indian NARS and Private Sector

Progress/Results:
ICRISAT has been engaged in the process of constant strengthening of its partnership with NARS of India, Myanmar, China, and members of the Pigeonpea Hybrid Parents Research Consortium (PHPRC). Through a series of meetings, field visits and informal talks, the partnership is further strengthened. During 2008/09 cropping season, scientists and pigeonpea breeding staff monitored multi-location trials and breeding materials planted at various locations by consortium partners. This includes Pioneer Overseas Corporation, Nath Biogene, Mahyco, Krishidhan Seeds, and Zuari Seeds. Some consortium partners and public seed company representatives who visited ICRISAT were from Mahyco, Krishidhan Seeds, JK Seeds, and National Seeds Corporation to monitor trials and learn about parental line (AxB) and hybrid seed (AxR) production technology. Scientists and staff from these companies interacted with ICRISAT scientists and had fruitful discussions about hybrid pigeonpea research and seed production technology.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium; Indian Council of Agriculture Research; National Food Security Mission of India
KB Saxena, CLL Gowda and RK Srivastava

Milestone 5A.7.1.5 Molecular markers and genetic maps developed and exchanged with the scientific community (RV/DAH/ KML/HDU/NM/KBS, 2010)

Achievement of Output Target:
70%

Participating Countries:
Australia, USA

Participating Partners:
University of California-Davis; DArT, Pty, Ltd

Progress/Results:
Development of microsatellites from Bacterial Artificial Chromosome (BAC) end sequences (BES): In collaboration with University of California, Davis (Doug Cook), a total of 87,590 pigeonpea BAC-end sequences (BES) were generated. These represented 56.5 Mb of genome, and were surveyed for the presence of microsatellites using MIcroSAtellite (*MISA*) search module. As a result, 18,149 pigeonpea microsatellites (1 SSR per 3.11 Kb) were identified. Primer pairs were designed for 6,590 SSRs, however, only 3,072 were selected for synthesis and were tested for amplification. As a result 3,026 primer pairs produced scorable amplification on 24 pigeonpea genotypes that are parents of different mapping populations segregating for *Fusarium* wilt (FW), sterility mosaic (SM) and water logging.

Gene based markers: An assembly of 454/FLX and Sanger sequence reads resulting in 127,754 tentative unique sequences (TUS) unigenes with an average length of 226 bp, were screened to evaluate the presence of SSR motifs using *MISA* search tool. This resulted in the identification of 41,899 (32.7%) sequences containing 50,566 SSRs with an average of one SSR per 570 bp. Of these 41,899 sequences, 6,997 (16.6 %) sequences contained more than one SSR and 6,352 (15.1%) were compound SSRs that have more than one repeat type. Primer pairs were designed for 12,377 SSRs including mononucleotide SSRs. A total of 8,023 primer pairs were considered for validation after excluding the primers for mononucleotide and compound SSRs.

SSR-enriched library: Several genomic DNA libraries enriched for five SSR repeat motifs (CT, TG, AG, AAG, and TCG) were generated from Asha variety using bead capture enrichment protocol. Initially, 1,728 clones were picked from two libraries and 82 clones were sequenced. This pilot experiment provided 36 SSRs from which 23 primer pairs were synthesized of which 16 provided scorable amplification products. Screening of 40 elite genotypes with these 16 markers indicated moderate polymorphism information content (PIC) values in the range of 0.05 to 0.55 with an average of 0.32 per marker. These results have been published in Plant Breeding (Saxena et al. 2009)

RK Varshney, A Dubey, NL Raju, Jayashree B,
RK Saxena, DR Cook and DA Hoisington

Development of genetic maps

A total of 554 DArT markers were detected in a pigeonpea mapping experiment using an F_2 mapping population of 72 progenies which were derived from an interspecific cross of ICP 28 (*Cajanus cajan*) × ICPW 94 (*Cajanus scarabaeoides*). Two groups of genetic maps were generated using DArT markers. A total of 121 unique DArT maternal markers were placed on the maternal linkage map. A total of 166 unique DArT paternal markers were placed on the paternal linkage map. The length of these two maps covered 437.3 cM and 648.8 cM, respectively.

In addition to above, genotyping of different mapping populations (inter- specific and intra- specific) with polymorphic markers as mentioned above is in progress.

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Output 5B: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners biennially (from 2008) with associated knowledge and capacity building in SAT Asia
Sorghum

Output target 2009 5B.1 At least five salinity-tolerant sorghum breeding lines/populations and a mapping population developed

Activity 5B.1.1 Developing/identifying salinity-tolerant improved breeding lines/populations and associated QTL

Milestone 5B.1.1.1 Five salinity-tolerant breeding lines/populations developed/identified (BVSR/VV, 2009)

Achievement of Output Target:
100%
Over the years, a number of trials have been performed, leading to the identification of superior breeding lines. These trials have been performed both under controlled environment conditions in pots, allowing yield to be assessed, and in the field trial using naturally saline field.

Participating Countries:
India

Participating Partners:
UAS Dharwad at Gangavathi

Progress/Results:
Based on the previous trial done in late 2008 and yield under saline conditions, the following entries were found to be contrasting for salinity tolerance. A non-saline control treatment and a saline treatment were used, with 3 replications. The saline treatment consisted of the equivalent of 150 mM solution of NaCl, in sufficient amount to saturate the soil profile of the Alfisol that was used. The salt treatment was not applied all in once but in split doses from the time of sowing to avoid a too rapid build up of the salinity (1/3 dose applied at sowing, 1/3 10 days later and the last dose at 20 days after sowing). Seed yield ranged between 10 and 70 g pot^{-1} in the non-saline control conditions, whereas it varied between 0 and 30 g pot^{-1} in the saline treatment. Contrary to other results, the seed yield under saline conditions was not related to the seed yield under control conditions.

Sensitive	Tolerant	Tolerant
ICSR 93024-1	ICSV 112	ICSA 52 x SPV 1411
ICSR 93034	ICSB 707	ICSA 405 x ICSV 93048
ICSV 93048	SP 47513	ICSA 675 x SSV 74
ICSR 170	ICSV 745	ICSA 405 x ICSV 96020
ICSB 406	NTJ 2	ICSA 405 x S 35
A 2267-2	SP 39105	ICSA 474 x SSV 74
ICSA 766 x ICSV 96020	ICSV 93046	ICSA 702 x SSV 74
ICSA 707 x ICSR 196	CSV 15	Ent 64 DTN
ICSA 276 x SPV 1022	SPV 1022	IS 21260
ICSA 766 x JJ 1041	ICSA 724 x SSV 74	296B
ICSR 91005	ICSA 405 x ICSV 93046	RSSV 9
ICSB 359	ICSA 405 x JJ 1041	SP 4511-3
ICSR 196	ICSA 276 x S 35	ICSB 276
ICSB 589	ICSA 405 x ICSR 93034	NSS 254
ICSB 401	CSH 16	ICSV 700
ICSB 405		SSV 84
ICSB 415		IS 23526
		SP 4487-3

Vincent Vadez and L Krishnamurthy

Milestone 5B.1.1.1 Five salinity-tolerant breeding lines/populations developed/identified (BVSR/VV, 2009)

Achievement of output target:
80%
A total of 638 F_7s and 189 F_6s for B-line development and 108 F_7s and 330 F_6s for R-line development (using salinity tolerant parents in the crossing program) were obtained with selection for high grain yield, bold grain and agronomic appearance. They need to be evaluated for salinity tolerance.

Participating Countries:
India and CAC countries

Participating Partners:
ICBA; NARS and Private sector in India; CAC countries

Progress/ Results:
For introgressing the salinity tolerance from selected salinity-tolerant B-lines, R-lines and varieties from earlier evaluations (such as ICSB 276, ICSB 301, ICSB 401, ICSB 405, ICSB 583, ICSB 699, ICSB 707 and ICSB 766 among the B-lines; ICSR 160, ICSR 170, ICSR 196, ICSR 89010 and ICSR 93034 among the R-lines and S 35, ICSV 112, ICSV 145, ICSV 700, ICSV 745, ICSV 93046, ICSV 93048, ICSV 96020, ICSV 95030, JJ 1041, CSV 15 and SPV 1022 among the varieties) into high-yielding background – a total of 638 F_7s and 189 F_6s for B-line development and 108 F_7s and 330 F_6s for R-line development were obtained with selection for high grain yield, bold grain and agronomic appearance. From the crosses between germplasm and breeding lines, 191 BC_1s (from 508 test crosses) and 77 F_6s with restorer reaction were selected for high grain yield and high biomass.

Other activities:

Screening of sweet sorghum material for midseason stress: A total of 400 sweet sorghum genotypes comprising of 100 B-lines and 170 R-lines/ varieties, 65 hybrids, and 58 germplasm accessions were evaluated along with five controls (ICSV 112: high grain yielding variety, R 16: drought susceptible control, B 35: stay green (drought tolerant) control, E 36-1: both stay green and sweet sorghum variety and NTJ 2: sweet sorghum variety) in augmented block design for mid-season moisture stress tolerance during Feb to Jun 2009. The data analysis revealed that among the B-lines SP 93035 (1.1 t ha⁻¹), ABT 2036-2 (0.8 t ha⁻¹); among the R-lines/varieties SP 08 2061-1 (2.3 t ha⁻¹), SP 08 2057-1 (1.9 t ha⁻¹); among the germplasm accessions IS 23530 (0.7 t ha⁻¹), IS 23525 (0.5 t ha⁻¹) and among the hybrids ICSA 324 × SSV74 (1.4 t ha⁻¹), ICSA 502 × SP 4481-1 (1.3 t ha⁻¹), gave comparatively high sugar yield *vis a vis* best control E36-1 (0.7 t ha⁻¹). For grain yield, among the B-lines SP 93035 (4.9 t ha⁻¹), ICSB 516 (4.4 t ha⁻¹); among the R-lines/varieties SP 08 2054-3 (4.76 t ha⁻¹), SP 08 1041-3 (4.14 t ha⁻¹); among the germplasm accessions IS 2325 (2.42 t ha⁻¹), IS 23530 (2.3 t ha⁻¹), and among the hybrids ICSA 502 × SP 4511-2 (3.6 t ha⁻¹), ICSA 511 × IS 15335 (3.4 t ha⁻¹), recorded high grain yield in comparison with the best control NTJ 2 (3.4 t ha⁻¹). Among the B-lines SP 2411, ICSB 24001; among the R-lines/varieties, SP 08 2015-3, SP 4495; among the germplasm accessions IS 23574, IS 23573; and among the hybrids ICSA 675 × SSV 74, ICSA 502 × SP 4511-2, had a rolling score of >4, firing score <2 and SP 08 2035-3, SP 08 2057-1, ICSB 669, ICSB 498, IS 3569, IS 25242, ICSA 675 × SP 4495, ICSA 724 × SP 4481-1, leaf angle score of 1 indicating their ability to cope up mid-season moisture stress. Under moisture stress, there was significant positive correlation between sugar yield and plant height (r=0.27), plant girth (r=0.33), cane weight (r=0.82), juice weight (r=0.96), juice volume (r=0.95) and bagasse yield (r=0.71).

Evaluation of drought-tolerant sweet sorghum genotypes in rainy season: A total of 95 genotypes comprising sweet sorghum hybrid parental lines, hybrids, varieties and germplasm accessions were evaluated along with five controls (ICSV 112: high grain yielding variety, R 16: drought susceptible control, B 35: stay-green (drought tolerant) control, E 36-1: both stay-green and sweet sorghum variety and NTJ 2: sweet sorghum variety) in a two-replicated trial in RCBD during July to November 2009. Data were recorded for days to 50% flowering, plant height, stem girth/ diameter, stalk weight, juice weight, Brix%, bagasse and sugar yield. Among these genotypes for sugar yield, the varieties SP 08 1047-2 (4.6 t ha⁻¹), SP 08 2038-1 (4.1 t ha⁻¹), SP 08 1040-3 (3.5 t ha⁻¹), SP 08 1052-2 (3.4 t ha⁻¹), SP 08 1022-3 (3.3 t ha⁻¹), SP 08 2045-1 (3.2 t ha⁻¹), SP 08 1019-3, SP 08 2006-3 (each 3.0 t ha⁻¹) and SP 08 2070-2 (2.9 t ha⁻¹) performed better than the best performing control CSH 22SS (2.9 t ha⁻¹). The hybrids, ICSA 89002 × SPV 422 (4.3 t ha⁻¹), ICSA 474 × ICSR 93034 (3.6 t ha⁻¹), ICSA 502 × SP 4481-1 (3.4 t ha⁻¹), ICSA 474 × SSV 74 (3.2 t ha⁻¹), ICSA 702 × SSV 84 (3.1 t ha⁻¹), ICSA 561 × SP 4487-1 (3.1 t ha⁻¹), ICSA 474 × NTJ 2 (3.05 t ha⁻¹), ICSA 502 × SP 4487-1 (3.0 t ha⁻¹), ICSA 73 × SP 4481-1(2.9 t ha⁻¹) performed better than the best performing control CSH 22SS (2.9 t ha⁻¹). Among these hybrids, the days to 50% flowering ranged from 72 to 81 days and the varieties flowered from 81 to 88 days (CSH 22SS: 85 days) indicating that the hybrids were earlier to flower than the varieties.

The same set of genotypes is being screened for terminal moisture stress and for postrainy season adaptation in 2009 postrainy season.

Belum VS Reddy, A Ashok Kumar and P Srinivasa Rao
Milestone 5B.1.1.2 New F_6 RIL mapping populations for salinity tolerance available for phenotyping and genotyping (CTH/SPD/BVSR/VV, 2009)

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
None

Progress/Results:
About 1780 F$_6$ RILs from 4 crosses were sown for generation advance to produce F$_7$ bulk seed during the postrainy season of 2009-10 following failure to advance these during the rainy seasons of 2008 (due to heavy damage by shootfly when sown later than recommended due to non-availability of irrigation water at the start of the season) and 2009 (not sown at all due to non-availability of irrigation water at the start of the season), but successful advance from F$_5$ to F$_6$ seed during the summer season of 2009:

Special Project Funding:
None

CT Hash, SP Deshpande, Belum VS Reddy and Vincent Vadez

Pearl millet

Output target 2009 5B.1 At least five salinity-tolerant improved breeding lines/ populations of pearl millet identified and feasibility of breeding salinity tolerant hybrids assessed (VV/KNR/SKG)

Activity 5B 1.1 Develop salinity-tolerant lines and populations in pearl millet and assess their hybrid potential under saline conditions

Milestone 5B.1.1.1 Inbred lines and populations identified as salinity-tolerant in preliminary evaluations re-evaluated for their salinity tolerance and yield potential (KNR/SKG/VV, 2008)

Achievement of Output Target:
60%
One trial has been fully completed in 2008, where a number of parental lines have been screened for salinity tolerance. A repeat screening has to be done to confirm the earlier results).

Participating Countries:
India and CAC countries

Participating Involved:
International Centre for Bio-saline Agriculture (ICBA)

Progress/Results:
A repeat screening of 70 pearl millet entries, including R-lines, B-lines and breeding materials and populations were tested in saline and non-saline conditions, in outdoor conditions, using a buried pot system where salinity stress can be homogenously applied. The trial carried out during the rainy season 2009 failed because of downy mildew in the control treatment and extreme severity of the saline treatment, due to a change in the soil lot. The trial will be repeated in 2010 using lower salt dose and ensuring that the soil is of good quality. No repeat of the sorghum material could be done this year for space limitation in the screening facility.

Special Project Funding:
OFID-OPEC-funded Project on Salinity Tolerance

KN Rai, SK Gupta, Vincent Vadez and L Krishnamurthy

Milestone 5B.1.1.2 Relationship between the salinity tolerance of hybrids and their parental lines assessed (KNR/RB/VV, 2010)

Since confirmed source of lines contracting for salinity tolerance has not yet been identified, this milestone is likely to be achieved by 2011.
KN Rai/SK Gupta/Vincent Vadez

Output target 2009 5B.2 Putative QTLs for salinity tolerance of grain and stover yield identified in pearl millet

Activity 5B.2.1 Genotyping and phenotyping of mapping populations for salinity tolerance

Milestone 5B.2.1.1 Putative QTL for salinity tolerance based on 160 RILs from one mapping population identified (CTH/SS/VV, 2009)

Achievement of Output Target:
100%
The work has been completed. QTL for seed yield and yield components have been identified, using the RIL population derived from cross 863B x ICMB841).

Participating Countries:
India

Participating Partners:
None

Process/Results:
One hundred and six F$_6$ RILs derived from cross CMB 841-P3 × 863B-P2 along with their parents were evaluated in pots for grain yield component traits under saline and control (non-saline) conditions (5 replicated pots per treatment, with 2 plants per replication) at ICRISAT-Patancheru during 2007 and 2008. Salt (2.733 g NaCl/kg of soil) was applied in three splits, the first at sowing and the other two doses within two weeks after sowing. Parent ICMB 841was more salt-tolerant than 863B. A linkage map using 77 SSR markers was constructed and composite interval mapping revealed a grain yield QTL on linkage group (LG) 3 which explained 13% of phenotypic variation under saline condition. Three genomic regions on LG 7 differing/sharing 30 cM had QTLs for plant height, panicle length (LOD 5), stem dry weight (LOD 4) and shoot dry weight under saline conditions with favorable allele(s) from ICMB 841. Among the three QTLs mapped for flowering time under saline condition, the LG 5 QTL was favored by the alleles from ICMB 841. For productive tiller number (LOD 3.3, r^2=17.4) and plant height (LOD 5, r^2=18), under saline conditions QTL was mapped on LG 1. For grain yield , flowering time

and productive tiller number, QTLs were on LG 3, 5 and 1, respectively, which expressed only under saline conditions with favorable allele contributed by ICMB 841. The QTLs mapped for control conditions were almost similar to the previous reports, a strong QTL (LOD 10, > 30% variation explained) was identified on LG 6 for individual grain mass under control conditions, with the favorable allele(s) contributed by 863B which confirm the previous experiment. QTLs identified in this experiment will be used to improve the salinity tolerance of pearl millet lines via marker-assisted introgression breeding.

Special Project Funding:
None

Sunita Choudhary, Vincent Vadez, CT Hash, T Nepolean and V Rajaram

Milestone 5B.2.1.2 Putative QTLs for salinity tolerance based on 35 BC6F3 contiguous segment introgression lines identified (CTH/SS/VV, 2010)

No report provided

Milestone 5B.2.1.3 New F_6 RIL mapping populations for salinity tolerance available in pearl millet for phenotyping and genotyping (CTH/KNR/VV, 2009)

Achievement of Output Target:
>75%

Participating Countries:
India

Participating Partners:
Indian Council of Agricultural Research (ICAR); All India Coordinated Pearl Millet Improvement Program, Jodhpur, Rajasthan, India

Progress/Results:
During summer 2009, 504 F_3 progenies derived from the single selfed F_1 plant (ICMB 01222-P1 × ICMB 95333-P1)-P1 were advanced to F_4 by modified single seed descent with selfing. These progenies were subsequently advanced to F_5 during a late rainy season sowing, and will be sown for advance to the F_6 generation during summer season of 2010. The resulting F_6 RILs will be available by the rainy season of 2010 for salinity tolerance phenotyping and genotyping to produce an SSR-anchored DArT-based linkage map for QTL mapping, provided that resources to support these activities are identified.

Special Project Funding:
ICAR grant for pearl millet marker-assisted breeding, entitled "Marker assisted breeding for pearl millet downy mildew resistance and terminal drought tolerance"

CT Hash, T Nepolean, KN Rai and Vincent Vadez

Output target 2009 5B.3 Breeding value of putative terminal drought tolerance QTLs in pearl millet documented

Activity 5B 3.1 Publication of earlier results on drought tolerance QTL and gene pyramiding

Milestone 5B.3.1.1 Publication of results from marker-assisted selection for the linkage group 2 drought tolerance QTL into the genetic background of two parental lines (CTH/FRB, 2008)

Achievement of Output Target:
100%
The work is completed. Several papers have been published. A high resolution cross is being developed to attempt fine mapping of the terminal drought tolerance QTL in LG2.

Participating Countries:
India, Ghana, UK

Participating Partners:
List partner institutions actually involved IBER (UK) – CSSRI - RAU

Special Project Funding:
DFID

CT Hash and FR Bidinger

Milestone 5B.3.1.1 Publication of results from marker-assisted selection for the linkage group 2 drought tolerance QTL into the genetic background of two parental lines (CTH/FRB, 2008)

Achievement of Output Target:
>75%

Participating Countries:
India, United Kingdom

Participating Partners:
Indian Council of Agricultural Research (ICAR); All India Coordinated Pearl Millet Improvement Program, Jodhpur, Rajasthan, India; Aberystwyth University, Abervstwyth, Wales, UK

Progress/Results:
At the InterDrought III conference in October 2009 a presentation was made of the results of three years phenotypic assessment of QTL introgression line testcross hybrid performance in stress-free and managed stress environments (at ICRISAT-Patancheru), and natural stress environments in drought-prone regions of the pearl millet production zone in northwestern India. The conference paper is being submitted to the Journal of Experimental Botany for publication in 2010.

CT Hash, T Nepolean, FR Bidinger, SMH Rizvi,
P Sathish Kumar and A Sharma

Milestone 5B.3.1.2 DM resistance and terminal drought tolerance QTLs pyramided in the genetic background of elite pollinator H 77/833-2 and QTL introgression homozygote product lines available for testing (CTH/PSK/SS/VV/RPT/RS/KNR, 2007)

Although the milestone was set for 2007, we have done additional work ever since. This year, we have focused on publishing the data from a number of experiments done with two pairs of tolerant/sensitive parents (PRLT-2/89-33 and H77/833-2; 863B and 841B). Some more detail about this work is reported in the MTP 2008, project 5. Here we provide a summary of the major results. .

Constitutive water conserving mechanisms: This work investigated whether the control of water loss under non-limiting water conditions is involved in the terminal drought tolerance of pearl millet. Two pairs of tolerant vs. sensitive pearl millet genotypes, PRLT 2/89-33 / H77/833-2 and 863B-P2 / ICMB 841-P3, and near- isogenic lines, introgressed with a terminal drought tolerance QTL from donor parent PRLT 2/89-33 into H77/833-2 (NILs-QTL), were tested. Upon exposure to water deficit, transpiration began to decline at lower fractions of transpirable soil water (FTSW) in tolerant than in sensitive genotypes, and NILs-QTL followed the pattern of tolerant parents. The transpiration rate (Tr, in g water loss cm^{-2} day^{-1}) under well-watered conditions was lower in tolerant than in sensitive parental genotypes and Tr of NILs-QTL followed the pattern of tolerant parents. In addition, Tr measured in detached leaves (g water loss cm^{-2} h^{-1}) from field-grown plants of the parental lines showed lower Tr values in tolerant parents. Defoliation led to an increase in Tr that was higher in sensitive than in tolerant genotypes. The differences in Tr between genotypes was not related to the stomata density (SD). These results demonstrate that constitutive traits controlling leaf water loss under well-watered conditions correlate with the terminal drought tolerance of pearl millet. Such traits may lead to more water being available for grain filling under terminal drought.

Sensitivity of transpiration to VPD and leaf ABA in pearl millet: We showed above that pearl millet genotypes carrying a terminal drought tolerance QTL had lower transpiration rate (Tr, g cm^{-2} d^{-1}) under well-watered conditions than sensitive lines. In this work we tested whether Tr relates to leaf ABA concentration and Tr at high vapor pressure deficit (VPD), and whether that leads to transpiration efficiency (TE) differences. These traits were measured in tolerant/sensitive pearl millet genotypes, including near-isogenic lines introgressed with a terminal drought tolerance QTL (NIL-QTLs). Most genotypic differences were found under well-watered conditions. ABA levels under well-watered conditions were higher in tolerant genotypes, including NIL-QTLs, than in sensitive ones and ABA did not increase under water-stress. Well-watered Tr was lower in tolerant than in sensitive genotypes at all VPD levels. Except for one line, Tr slowed down in tolerant lines above a breakpoint at 1.40-1.90 kPa, with the slope decreasing more than 50%, whereas sensitive lines showed no change in Tr response across the whole VPD range. It is concluded that two water saving (avoidance) mechanisms may operate under well-watered conditions in tolerant pearl millet: (i) a low Tr even at low VPD conditions, which may relate to leaf ABA; (ii) a sensitivity to higher VPD that further restricts Tr, which suggests the involvement of hydraulic signals. Both traits, which did not lead to TE differences, could contribute to absolute water saving seen in part from dry weight increase differences. This water saved would become critical for grain filling and deserves consideration in the breeding for terminal drought tolerance.

Vincent Vadez, Jana Kholova and Tom Hash

Milestone 5B.3.1.2 DM resistance and terminal drought tolerance QTLs pyramided in the genetic background of elite pollinator H 77/833-2 and QTL introgression homozygote product lines available for testing (CTH/PSK/SS/VV/RPT/RS/KNR, 2007)

Achievement of Output Target:
100%

Participating Countries:
India, United Kingdom

Participating Partners:
Indian Council of Agricultural Research (ICAR); All-India Coordinated Pearl Millet Improvement Program, Jodhpur, Rajasthan, India; Aberystwyth University, Aberystwyth, Wales, UK

Progress/Results:
During 2009 we identified 8 potentially desirable segregants among more than 2300 F_2 individuals derived from self-pollination of two F_1 plants from a single plant × plant cross of downy mildew resistance QTL introgression line ICMR 01004 (BC 4 derivative having downy mildew resistance QTLs on LG1 and LG4 from donor parent ICMP 451-P6 in the genetic background of elite pollinator H 77/833-2) and drought tolerance QTL introgression line ICMR 01029 (BC4 derivative having a major drought tolerance QTL on LG2 from donor parent PRLT 2/89-33 in the genetic background of the same elite pollinator line, namely H 77/833-2). Selfed seed from 7 of these potentially desirable F_2 segregants (homozygous for SSR marker alleles of ICMP 451 flanking the downy mildew resistance QTLs in LG1 and LG4, and homozygous for SSR marker alleles of PRLT 2/89-33 across the full genotyped length of LG2) was multiplied (advancing inbreeding to the F_4 seed generation) for additional downy mildew screening and production of testcross hybrid seed during the 2010 summer season.

CT Hash, T Nepolean, S Senthilvel, RP Thakur and Rajan Sharma

Output target 2009 5B.4 Pearl millet germplasm with superior P-acquisition identified

Activity 5B 4.1 Development of an effective protocol and identification of germplasm with enhanced P-acquisition ability

Milestone 5B.4.1.2 Pearl millet germplasm with superior P-acquisition from low-P sources identified (VV, 2009)

Achievement of Output Target:
100%
Reported in 2008. Additional work on seed coating is presented below, demonstrating the dramatic effect of coating seeds with P on their early growth and on time to flowering.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Experiments were carried out in green house and field-like conditions to evaluate the effect of seed priming and seed coating with P source on shoot biomass and yield of pearl millet in low-P soil. Seed priming was not a valid option to apply P to pearl millet seeds whereas seed coating showed clear beneficial effects. Seed coating with P nutrient source (KH_2PO_4) increased the vegetative biomass in the early stages by 300 % and panicle yield by about 50 % over the non coated treatment. Although P deficiency delayed the time to 50% flowering by about 20 days compared to the non-limiting P treatment, plants in the seed coating treatment flowered 10 days earlier than the non-coated control. The seed coating treatment in field-like conditions led to biomass being similar or 15% less only than in the non-limiting P treatment. In these conditions, the seed yield was also dramatically increased by the coating treatment (45-65% higher than the non-coated treatment), although seed yield remained 25-35% lower than in the non-limiting P treatment. These results show that the seed P coating treatment is a valid option to promote pearl millet seedling establishment as it helps boosting yield under low soil P conditions. We hypothesize that the positive effect on yield, even in pots offering a limited soil volume comes from an early effect of the seed coating on the developmental processes taking place before panicle initiation.

Special Project Funding:
None

<div align="right">Padmaja Karanam, Vincent Vadez and Michael Blummel</div>

Milestone 5B.4.1.3 QTL for P acquisition from low P sources identified in pearl millet (VV/CTH, 2011)
No report provided

Output target 2009 5B.5 At least five pearl millet breeding lines with tolerance to high air temperatures (>45°C) during reproductive stage developed

Activity 5B 5.1 Evaluate a diverse range of parental lines, advanced breeding lines and populations for high temperature tolerance during flowering and grain- filling period; and identify major QTL associated with this trait

Milestone 5B.5.1.1 Breeding lines with >70% seedset under field conditions at high temperatures identified/developed and their tolerance under greenhouse conditions validated (KNR/SKG/VV, 2009)

Achievement of Output Target:
Nil

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
We have tested 16 testcross hybrids of pearl millet, including materials introgressed with a terminal drought tolerance QTL, in two seasons having differences in air temperature. Two trials were planted, respectively, on Feb 3rd and March 3rd. Genotypes flowered around March 10th in the first trial and about a month later in the second trial. Plants were grown in 2.0m long, 25 cm diameter cylinder, one plant per cylinder, under either well-watered conditions or under terminal stress (last watering at booting). Ten replications per genotype and treatment were used. The max and min air temperatures were 34.2 and 18.2 ºC in the first trial around the time of flowering (10-20 March 2009), and 37.9 and 22.8 ºC in the second trial (10-20 April 2009). The yield of PRLT-2/89-33 decreased by about 25% due to the higher temperature conditions, whereas the yield of H77/833-2 did not decrease at all. Shoot (leaf or stem) biomass did not decrease at all in any of the entries tested, indicating that the effect of temperature was on seed setting.

<div align="right">Vincent Vadez and CT Hash</div>

Milestone 5B.5.1.2 Relationship between hybrids and their parental lines for tolerance to high temperatures during reproductive stage quantified (KNR/SKG/VV, 2010)

It is yet to be initiated after identifying/developing lines confirmed for heat tolerance under the above milestone.

Milestone 5.1.3 QTL for high temperature tolerance from two diverse mapping populations identified (KNR/SKG/VV, 2012)

It is yet to be initiated after identifying/developing lines confirmed for heat tolerance under the milestones 5B.5.1.1.

Output 5C: Germplasm and improved breeding lines with high and stable grain Fe and Zn density in sorghum and pearl millet made available to specific partners biennially (from 2008) with associated knowledge and capacity building

Sorghum

Output target 2009 5C.1 Sorghum germplasm lines/breeding lines with stable and high grain Fe (40-50 ppm) and Zn (30-40 ppm) contents identified and their character association, and inheritance studied

Activity 5C 1.2 Conduct inheritance studies and develop mapping populations for Fe and Zn.

Milestone 5C.1.2.1 Genetics of grain Fe and Zn established (BVSR, 2009)

Achievement of Output Target:
60%
Crosses were made using contrasting parents and the crosses along with parents are under evaluation for studying the inheritance

Participating Countries:
India , Mali

Participating Partners:
NARS and Private sector in India and Mali

Progress/Results:
Crosses (2-3) will be made using contrasting parents and different generations (F_1, F_2, BC_1 and BC_2) developed to study the inheritance of grain Fe and Zn contents.

For studying the gene action, the progenies from emasculated crosses developed using contrasting parents comprising 28 F_1s and six parents for grain Fe content; 12 F_1s and four parents for grain Zn content; and 19 F_1 generations and five parents for studying grain Fe and Zn contents along with control (ICSR 40) are under evaluation in 2009 postrainy season for establishing the inheritance of grain Fe, grain Zn and grain Fe and Zn contents. The grain analysis for Fe and Zn contents will be carried out in 2010.

Special Project Funding:
HarvestPlus Challenge Program

<div align="right">A Ashok Kumar and Belum VS Reddy</div>

Pearl millet

Output target 2009 5C.1 Magnitude of variability for grain iron (Fe) and zinc (Zn) in more than 300 inbred lines, 50 improved populations, 400 germplasm accessions, and 40 commercial hybrids of pearl millet quantified, and at least three lines and three populations with high levels of Fe (65-75 ppm) and Zn (45-55 ppm) identified

Activity 5C1.1 Evaluation of germplasm, breeding lines and improved populations for grain Fe and Zn contents

Milestone 5C.1.1.2 Variability for Fe and Zn in iniari germplasm, core collection and commercial hybrids assessed (KNR/SKG/HDU/KLS, 2008)

More than 280 *iniari* accessions were evaluated in 2009 summer season and grain samples were produced for 274 accessions. The ICP analysis of these lines showed Fe ranging from 91 to 172 ppm and Zn ranging from 61 to 138 ppm. Same set was repeated in 2009 rainy season and grain samples produced were sent for ICP analysis. One hundred large-seeded non-*iniari* accessions were also evaluated during 2008/2009 post-rainy season, and grain samples were produced for Fe/Zn estimation. Results of core collection and commercial hybrids have been reported under Output target 2009 5.3.1 SOPM.

Milestone 5C.1.1.3 GxE interaction for Fe abd Zn assessed and lines stable for >70 ppm Fe abd >50 ppm Zn identified (KNR/SKG/KLS, 2009)

Multilocation trials of two sets for stability analysis were continued. Set-1 trial, consisting of 30 entries was sent to 13 locations in 2009 rainy season and grain samples were received from 8 locations. Set-2 trial, consisting of 20 populations was sent to 9 locations in 2009 rainy season and grain samples were received from 6 locations. Thus, for the set I trials conducted in 2007 and 2009, grain samples have now been received from 14 environments (year/location), and for set II trial conducted in 2008 and 2009, grain samples have been received from 12 environments. This completes multi-location stability trials. These grain samples will now be analyzed for Fe and Zn contents

Output target 2009 5C.2 Information on genetics and recurrent selection efficiency for grain Fe and Zn available

Activity 5C2.1 Conduct genetical studies and recurrent selection for grain Fe and Zn contents and develop mapping populations

Milestone 5C.2.1.1 Inheritance of Fe and Zn and relationship between the parental lines and hybrids for these traits determined (KNR/SKG/KLS, 2009)

Reported under output target 2010 5.3.2 SOPM

Milestone 5C.2.1.2 Effectiveness of S_1 recurrent selection for Fe and Zn, and its effect on grain yield and other agronomic traits in four populations quantified (KNR/SKG/KLS, 2012)

Results of recurrent selection in two populations have been reported earlier (2008 Archival Report). Progress made in recurrent selection on the other two populations are reported under output target 2012 5.3.1. SOPM

Milestone 5C.2.1.3 QTL for high grain Fe and Zn identified based on F6 RIL mapping populations from two crosses (CTH/SS/KNR, 2010)

Achievement of Output Target:
75%

Participating Countries:
India

Participating Partners:
Rajasthan Agricultural University, Bikaner, India; Indian Council of Agricultural Research (ICAR), All-India Coordinated Pearl Millet Improvement Program, Jodhpur, Rajasthan, India

Progress/Results:
Using 78 SSR markers, a linkage map was constructed for a (ICMB 841-P3 × 863B-P2)-based pearl millet RIL mapping population. Fe and Zn concentrations of replicated grain samples of 106 RILs were measured with Atomic Absorption Spectroscopy. Grain mineral concentrations ranged from 38.1 to 82.7 ppm for Fe and 39.1 to 81.6 ppm for Zn. Five putative QTLs for micronutrient concentrations were identified by Composite Interval Mapping, of which four were for Fe-one each on linkage group 2 (LG2) and LG5, and two on LG7 — and one for Zn (on LG3). Together the four Fe QTLs explained only 11% of observed phenotypic variation, whereas the Zn QTL mapped on LG3 explained 14% of observed phenotypic variation. The RIL mapping population trial was repeated in a late rainy season sowing at ICRISAT-Patancheru in 2009, and grain samples (both self-pollinated and open-pollinated) were collected from two replications of 120 entries. The trial will be further repeated during the summer 2010 season. Grain samples from the 2009 trial are now being processed for analysis of their zinc and iron contents. Once these phenotyping data are available, we will repeat the QTL analysis for this RIL population.

Marker-assisted backcrossing (MABC) was initiated to improve grain Zn content of 14 elite hybrid parental lines by foreground selection for 863B-P2 donor alleles flanking the LG3 QTL, combined with background selection to hasten recurrent parent genome recovery. Following marker-based selection among BC_1F_1 individuals, $BC_2 F_1$ progenies were generated in late *kharif* 2009. These will be advanced to BC_3F_1/BC_2F_2 generation pairs in summer 2010 to fix the introgressed QTL. This effort will lead to production of superior pearl millet hybrids with improved grain zinc content.

Finally, two additional pearl millet RIL populations were advanced to F_6/F_7 generation during 2009 and progeny sets of these are to be sown in replicated field trials at ICRISAT-Patancheru during the summer season and rainy season of 2010 to produce grain samples for phenotyping zinc and iron contents. These two F_7 RIL populations each include more than 300 progenies each from two crosses.

Special Project Funding:
ICAR; Generation Challenge Program

CT Hash, T Nepolean, S Senthilvel and KN Rai

Other activities

➤ Based on large seed size, 54 S_1 progenies from a Large-Seeded Gene Pool and 190 progenies from Bold-Seeded Early Composite were produced during 2009 summer season. These along with 54 large-seeded B-lines were planted in an unreplicated nursery in rainy season and 305 grain samples were produced for mineral analysis.

➤ More than 1300 potential restorer-lines and 500 potential seed parental lines were screened using Perls Prussian blue staining method during January and February 2009. Of these, 897 potential restorer lines and 350 potential seed parent lines that revealed dark to light blue stain (putatively high to moderate Fe levels) were selected. From the selected potential restorer lines, initially a set of 467 lines was evaluated in a 3-replication trial in 2009 summer season. Grain samples were produced from all the three replications for Fe/Zn estimation. Grain samples of 458 advanced breeding lines from the restorer development program produced from two replications in the summer season were screened for the Fe and Zn content using NIRS method. Results of this preliminary screening showed large variability among the lines both for the Fe content (29-143 ppm) and Zn content (47-95ppm). The remaining 430 potential restorer lines and 350 seed parents lines were planted in unreplicated nursery during the rainy season and grain samples produced were sent for ICP analysis.

➤ To examine the extent of within-population variability in germplasm accessions, 45 S_1 progenies produced from each of four high Fe/Zn *iniari* accessions (IP 9439, IP 9457, IP 17521 and IP 17672) were evaluated along with 5 checks in a 2-replication trial at Patancheru in 2009 summer season. Grain samples were produced from both the replications for each of the four accessions for Fe/Zn estimation. The replicated S_1 trials of three accessions (IP 9439, IP 9457and IP 17521) were repeated in the rainy season and grain samples were produced.

➤ For character association studies, 40 S_1 progenies were derived from each of the two populations (AIMP 92901 and ICMR 312) in 2009 summer season. These were planted in 3 replications in 3-row plots for agronomic evaluation and grain production for mineral analysis during the rainy season. The first row was used for selfing and grain sample production for Fe/Zn analysis. Other two rows were used for agronomic and grain yield data. A similar trial of two other populations (ICTP 8203 and JBV 3) evaluated in the summer season was repeated. Grain samples of ICTP 8203 and JBV 3 produced in the summer season has been sent for mineral analysis.

➤ Four selfing generations and original bulks (C0, S1, S2, S3, S4) of each of three composites were evaluated in a 3- replication trial in 2009 summer season to study the effect of inbreeding on grain Fe/Zn density. Grain samples were produced from all the three replications for Fe/Zn estimation.

➤ Twelve pairs of tall and dwarf near- isogenic lines were evaluated in a 3-replication trial in 2009 summer season to study effect of plant height on grain Fe/Zn content. Grain samples were produced from all the three replications for Fe/Zn estimation.

➤ The C_0, S_1, S_2, S_3, and S_4 bulks of each of three composites and 9 pairs of tall and dwarf near- isogenic lines were evaluated separately in a 3-replication trial in 2009 summer season in drought nursery and under irrigated controlled conditions to study the effect of terminal drought on Fe/Zn content. Grain samples were produced from all the three replications for Fe/Zn estimation.

- Twenty F_1s produced by crossing two grey-seeded line as female parent with 10-white seeded lines as male parent during 2008 rainy were evaluated in a two replication trial in 2009 summer season. The F_2 seeds produced from each F_1s were grouped into two classes (grey and white) to study the effect of grain color on Fe/Zn density. ICP analysis of the grain samples showed 84-114 ppm Fe in the two grey color lines and 17-110 ppm Fe in the 10 white color lines. The grey color F_2 seed had Fe 53-126 ppm Fe and white color F_2 seed had 54-128 ppm Fe. The mean Fe content of grey color seed (92 ppm) was similar to that in the white color (91 ppm), indicating that seed color is not associated with Fe content. The Fe content of 20 grey color seed was highly correlated with those having white grain color (r^2=0.9). This trial was repeated in the rainy season and grain samples were produced.

- Sixteen lines were planted in 4-row plots in 3 replications in the rainy season. About 50 plants were bagged in each plot. At the stigma stage, the selfing bags were pushed up and down to various degrees to damage the stigma and thus achieve varying levels of selfed seed set. At harvest, panicles were classified into three distinct seed set classes (poor: 5-20%, average: 40-50% and good: 80-100). Those panicles not conforming to these seed set classes were discarded. Thus, a total of 144 seed samples (16 lines x 3 seed set classes x 3 replications) were produced and analyzed for Fe and Zn content using ICP protocol. Results showed that the mean Fe content of lines in good seed set class was 76 ppm (range: 52-103 ppm). In the average seed set class, the mean was 87 ppm and range was 57-115 ppm (14% more compared to good seed set class, varying from 7 to 31%). In the poor seed set class, the mean was 108 ppm and range was 71-136 ppm (41% more compared to good seed set class, varying from 15 to 62%). This showed that reduced seed set under selfing may give inflated values of Fe content, and hence seed set should be systematically recorded and be considered as an important criterion in selecting for Fe content. Similar pattern was found for Zn content as well.

- Eighty one F_1s were produced by crossing among the high-Fe B- lines and additional 53 F_1s were produced by crossing high-Fe B- lines with high-Fe lines of CGP and GGP progenies in 2009 summer season. All the 134 F_1s were planted in 2009 rainy season and F_2 seeds were produced. Eighteen F_2s derived from high iron B x B crosses were planted in November for rapid generation advance.

- Three hundred twenty potential B-lines identified for high Fe, based on the staining procedure, were crossed on A_1-and A_4-system male-sterile lines and 560 testcross hybrids were produced to evaluate their male sterility reaction. Similarly, 328 potential restorer lines were crossed with A_1/A_4 CMS lines, and 400 testcrosses were developed, which were evaluated during the rainy season for male fertility restoration.

- More than 150 potential R-lines and 5 A/B lines were involved in the development of 408 hybrids for southern zone, and 119 potential R-lines and 12 B-lines were involved in the development of 404 hybrids for north zone during 2009 summer season. This was grouped into four testcrosses trials and trials of their parental lines. Testcross trial 1 and 2, and the trials of their parental lines were conducted in peninsular India. Similarly, testcross trial 3 and 4, and the trials of their parental lines were conducted in northern India. Parental trial-1 consisting of 5 B-lines and 70 R-lines was evaluated at 3 locations. Parental trial- 2 consisting of 5 B-lines and 85 R-lines was evaluated at 3 locations. Parental trial-3 consisting of 12 B-lines and 52 R-lines was evaluated at 3 locations. Parental trial-4 consisting 6 B-lines and 67 R-lines was evaluated at 3 locations. All trials were also conducted at Patancheru. Grain samples were received from Parental trial-1 (370 samples from 2 locations), Parental trial-2 (200 samples from 1 location), Parental trial-3 (312 samples from 2 locations and from Parental trial-4 (142 samples from 1 location). Also, 657 grain samples were produced at Patancheru from all the 4 trials. These are yet to be analyzed for grain Fe and Zn content.

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MTP Project 6: **Producing More and Better Food at Lower Cost of Stable Open-Pollinated Cereals and Legumes (Sorghum, Pigeonpea, Chickpea and Groundnut) Through Genetic Improvement in the Asian SAT**

Project Coordinator: **PM Gaur**

Highlights for 2009

Chickpea
- Kabuli chickpea breeding lines with extra-large seed (>50 g 100-seed^{-1}), early to medium maturity (94-105 days) and high resistance to fusarium wilt (< 10% mortality) developed and made available to NARS partners.
- Desi chickpea breeding lines with combined resistance to ascochyta blight, botrytis grey mould and fusarium wilt developed. Some of these lines (ICCV 05527, ICCV 05528, ICCV 05529) showed high levels of fusarium wilt resistance at multilocation trials conducted in India.
- A major QTLs (about 33% of the variation) for drought avoidance root traits earlier identified from ICC 4958 x Annigeri RILs was validated in ICC 4958 x ICC 1882 RILs. This QTL is now being introgressed in a farmer-preferred cultivar (JG 11) through marker-assisted back crossing (MABC)

Pigeonpea
- F$_2$ populations for molecular mapping of genes controlling fusarium wilt and sterility mosaic diseases developed based on molecular and phenotypic variation between the parental lines.
- New sources of resistance to fusarium wilt and sterility mosaic identified (e.g. ICP 9174 and ICPLs 20094, 20098, 20099 and 20106) and made available to NARS partners.
- A screening of 300 accessions for salinity tolerance revealed large variation for salinity susceptibility index (SSI) and percent relative reduction in biomass under saline condition as compared to non-saline conditions. Several salinity tolerant accessions were identified in the cultivated (e.g. ICP 8860, 7803, 7260, 6815, 10654, 3046, 2746,7426,10559, 7057, 6049, 6859 and 7) and the wild species (ICPW 87, 94 and 68).

Groundnut
- The short-duration, drought tolerant groundnut variety ICCV 91114, earlier released in Andhra Pradesh and Orissa, was released in Karnataka.
- Six selected T7 transgenic events carrying the *DREB1A* gene driven by the stress-responsive *rd29A* gene promoter were evaluated for yield under a contained field strip trial. Under drought stress, yield in terms of pod and seed dry weight was found to be significantly higher in the transgenic event RD11 compared to other transgenic events as well as the controls i.e., JL24, and ICGV 86031.
- Four transgenic events carrying *RChit* gene that previously showed higher chitinase activity were screened for Late leaf Spot (LLS) and Rust diseases using detached leaf bioassays. All transgenic events showed significantly higher latent period as compared to non-transgenic control for both the diseases.

Sorghum
- Sorghum varieties with high resistance (score of 2.0) to grain mold and high yield potential were developed both SP 25831-1 with cream grain color and SP 25638-1 with white grain color.

Output 6.1: Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of breeding methods and capacity building made available to partners internationally

Output target 2009 6.1.1 CP 10 Kabuli chickpea breeding lines with extra large seed (greater than 50 g 100 seeds^{-1}) and high resistance to fusarium wilt developed

Achievement of Output Target:
100%
Kabuli chickpea breeding lines with extra large seed (> 50 g 100-seed^{-1}) and high resistance to fusarium wilt developed and supplied to NARS partners

Participating Countries:
India

Participating Partners:
Indian Institute of Pulses Research, Kanpur; Mahatma Phule Krishi Vidyapeeth, Rahuri; Indian Agricultural Research Institute, New Delhi; Punjab Agricultural University, Ludhiana

Progress/Results:
Development of fusarium wilt (FW) resistant extra-large seeded kabuli chickpea breeding lines: Looking at the increasing demand of extra-large kabuli chickpea cultivars in India and other countries, a breeding program was initiated to develop breeding lines with extra-large seed (seed size >50g 100-seed^{-1}), early to medium maturity and high resistance to FW. Twenty selected F$_6$ progenies of large seeded kabuli chickpea were made available to NARS partners in India. One set of these lines was evaluated at ICRISAT, Patancheru in normal field (4-row plots) for phenology, seed size, and yield and another set (one-row plots) in wilt sick field. Ten lines had 100-seed weight more than 50 g and five of these lines exceeded the best check for seed size ICC 17109 (100-seed weight: 53.6 g) (Table 6.1). The line ICCX-030157-F4-P9-BP-BP had the highest 100-seed weight (65.2 g) followed by ICCX-030138-F4--P4-BP-BP (62.1 g). These two lines also showed high resistance (<10% mortality) to fusarium wilt. The maturity duration in the lines was in the range of 94 to 105 days. Among the progenies, highest yield was obtained in the line ICCX-030151-F4-P2-BP-BP (1771 kg ha^{-1}) followed by ICCX-030141-F4-P16-BP-BP which yielded 1746 kg ha^{-1}.

Table 1. Performance of 20 F$_6$ progenies evaluated during 2008/09 at ICRISAT.

Pedigree	Days to 50% flowering	Days to Maturity	Plant height (cm)	100-seed weight (g)	Harvest Index (%)	Yield (kg/ha)	Wilt (%)
ICCX-030138-F4-P4-BP-BP	46	104	43.0	62.1	63.1	1483	0.0
ICCX-030141-F4-P16-BP-BP	42	103	43.2	46.5	56.6	1746	41.7
ICCX-030141-F4-P19-BP-BP	38	104	46.2	48.6	53.3	1527	20.0
ICCX-030144-F4-P2-BP-BP	52	105	44.6	57.5	59.4	1691	80.0
ICCX-030151-F4-P2-BP-BP	41	98	47.4	48.1	58.4	1771	25.0
ICCX-030155-F4-P15-BP-BP	42	103	43.8	46.5	41.6	1189	60.0
ICCX-030157-F4-P5-BP-BP	39	94	44.6	59.5	61.6	1527	29.4
ICCX-030157-F4-P9-BP-BP	41	103	42.4	65.2	68.2	1477	7.1
ICCX-030160-F4-P4-BP-BP	37	95	48.2	54.6	59.7	1329	20.0
ICCX-030163-F4-P19-BP-BP	38	95	41.0	42.7	59.3	844	42.9
ICCX-030177-F4-P18-BP-BP	42	105	45.2	52.5	50.8	789	31.3
ICCX-030177-F4-P28-BP-BP	44	104	49.6	43.4	46.2	1189	27.3
ICCX-030178-F4-P9-BP-BP	38	104	40.3	45.0	51.9	1535	38.5
ICCX-030185-F4-P11-BP-BP	33	97	40.0	42.8	53.3	1521	28.6
ICCX-030185-F4-P13-BP-BP	38	95	42.2	42.8	55.1	825	40.0
ICCX-030199-F4-P22-BP-BP	39	104	42.4	51.9	49.9	1671	21.1
ICCX-030199-F4-P7-BP-BP	38	103	44.2	47.5	51.9	1214	33.3
ICCX-030208-F4-P6-BP-BP	44	103	47.2	51.4	52.5	1716	37.5
ICCX-030208-F4-P7-BP-BP	43	104	42.8	53.6	50.2	1427	25.0
ICCX-030208-F4-P8-BP-BP	43	102	48.6	50.9	54.4	1510	10.0
ICC 17109	41	103	47.0	53.6	55.6	1485	18.2
ICC 14194	39	103	42.4	45.7	48.3	1496	13.6
KAK 2	38	92	36.0	38.9	46.6	2366	30.0
ICCV 95334	44	103	46.0	46.6	53.9	1479	36.8

In addition to these, there are several breeding lines in the pipeline for further evaluation and 56 segregating populations (23 in F$_3$ and 33 in F$_4$) for selection of plants for development of progenies.

PM Gaur, Shailesh Tripathi, CLL Gowda,
Suresh Pande and Mamta Sharma

Output target 2009 6.1.1 PP Molecular characterization of wilt/sterility mosaic resistant and susceptible germplasm/breeding lines to identify diverse parents for developing mapping populations

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
None

Progress/Results

As mentioned in Archival report 2008, molecular characterization of the germplasm lines for *Fusarium* wilt (FW) and sterility mosaic disease (SMD) resistance was accomplished. Based on these molecular diversity data together with phenotyping data, a total of five parental combinations were identified and used for crossing. To confirm the hybridity of F1 plants, 10-15 SSR markers were used. Subsequently, the F$_1$s were advanced to F$_2$ populations. A set of 384 F$_2$ plants have been generated in four combinations [ICPB 2049 × ICPL 99050 (FW), ICP 8863 × ICPL 20097 (SMD), ICPL 332 × ICPL 20096 (FW and SMD) and ICPL 87119 × ICPL 87091 (FW and SMD)], but F$_2$s could not be recovered for ICPL 332 × ICP 7035. Subsequently DNA has been extracted from all 384 F$_2$ individuals of all four crosses mentioned above. Thus, in summary, four mapping populations are presently available for phenotyping and genotyping for mapping of resistance loci to Fusarium wilt and sterility mosaic disease.

RK Varshney, RK Saxena, S Pande, KB Saxena and RK Srivastava

Output target 2009 6.1.2 PP 15 new sources of resistance to wilt and sterility mosaic virus identified and made available to partners

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
SAUs and ICAR Institutes

Progress/Results**:**
To identify stable and broad based resistance to fusarium wilt (FW) and sterility mosaic disease (SMD), pigeonpea lines having combined resistance to FW and SMD identified at ICRISAT-Patancheru were evaluated for resistance to both these disease at different locations in India through pigeonpea wilt and sterility mosaic disease nursery (PWSMDN). PWSMDN consisted of 30 entries, 28 entries were resistant to both wilt and SMD at ICRISAT-Patancheru and the other two were wilt susceptible (ICP 2376) and SMD susceptible (ICP 8863) checks. Additionally, two local susceptible checks, one for wilt and the other for SMD were also included from the participating location. The nursery was evaluated at 19 locations (Akola, Badnapur, Bangalore, Berhampore, Coimbatore, Dholi, Faizabad, Gulbarga, Hazaribag, ICRISAT-Patancheru, Kanpur, Khargone, Vamban (Pudukottai), Raipur, Rahuri, Sehore, S K Nagar, Vadodara (Gujarat) and Varanasi) in India. In most of the locations the nursery was planted in wilt sick plot and every plant of the nursery was inoculated with SMD infested pigeonpea leaves using leaf staple technique at two leaf stage wherever possible and if not, SMD infested twigs were spread on the plants of the nursery at seedling stage for SMD development. Data on FW and SMD was recorded twice, at flowering and at maturity stages of the crop.

Data on wilt was received from 11 locations (Badnapur, Bangalore, Dholi, Gulbarga, Kanpur, ICRISAT-Patancheru, Khargone, Rahuri, Sehore, Vadodara and Vamban). Of the 28 entries, one entry (ICPL 20096) was found asymptomatic/ resistant (<10.0% incidence) in all eleven locations, two entries (ICPL's 20102 and 20126) were found asymptomatic/ resistant (<10.0% incidence) in ten locations, seven entries (ICP 9174, ICPL's 20098, 20106, 20109, 20116, 20120, and 20129) at nine locations and six entries (ICPL's 20099, 20101, 20110, 20115, 20128 and 20132) at eight locations and eight entries (KPBR- 80-2-4, ICPL's –20093, 20094, 20100, 20103, 20113, 20114 and 20134) at seven locations were found asymptomatic/ resistant to wilt.

Data on SMD was received from nine locations (Badnapur, Bangalore, Coimbatore, Dholi, ICRISAT-Patancheru, Rahuri, Vadodara, Vamban and Varanasi). In Vadodara in local susceptible check (ICP 8863), no incidence of SMD was recorded, hence data was not compiled. Of the 28 entries, two entries (ICPL 20094 and KPBR-80-2-4) were found asymtomatic/ resistant (<10% incidence) at five locations. Nine entries were found asymptomatic/ resistant at four locations (ICP 9174, ICP 12749, ICP 14819, 20096, 20098, 20099, 20106, 20107 and 20115) to SMD.

Special Project Funding:
None

<div align="right">Suresh Pande, Mamta Sharma and Collaborators</div>

Output target 2009 6.1.3 PP At least 10 germplasm/breeding lines with resistance to Helicoverpa identified and made available to partners

Achievement of Output Target:
50%
Several lines with pod borer resistance have been identified and their stability studied, and new lines are being developed and evaluated.

Participating Countries:
India

Participating Partners:
Indian Institute of Pulses Research

Special Project Funding:
ISOPOM project on *Helicoverpa* resistance

Progress/Results:
Evaluation of pigeonpea germplasm for resistance to pod borer, *Helicoverpa armigera*: We evaluated 146 pigeonpea germplasm accessions for resistance to *H. armigera* along with resistant and susceptible checks under field conditions. There were three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 rating scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), and grain yield. The genotypes ICP 7, ICP 655, ICP 772, ICP 1071, ICP 3046, ICP 4575, ICP 6128, ICP 8860, ICP 12142, ICP 14471, and ICP 14701 exhibited moderate levels of resistance (damage rating 5.0 as compared to 9.0 in ICPL 87) to pod borer, *H. armigera* and these lines also showed good yield potential (850 to 1540 kg ha^{-1}) under unprotected conditions, and also had no wilt incidence as compared to 38.2% wilt in ICP 8266.

<div align="right">HC Sharma and HD Upadhyaya</div>

Evaluation of short-duration pigeonpea genotypes for stability of resistance to pod borer, *Helicoverpa armigera*: We evaluated 12 pigeonpea genotypes for resistance to *H. armigera* under field conditions. There were two replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 damage rating (DR) scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), egg and larval numbers, and grain yield. The genotypes ICP 7203-1, ICPL 187-1, T 21, UPAS 120, and ENT 11 suffered moderate levels of pod borer damage (DR 4.5 to 5.5) as compared to ICPL 87 (DR 7.5). Pod damage was 22.33 to 46.91% in ICP 7203-1, ICPL 187-1, ICPL 269, ICPL 88039, ICPL 98008, PPE 45-2 and UPAS 120 as compared to 77.92% pod damage in ICPL 88032 and 60% pod damage in ICPL 87, of

which ICP 7203-1, ICPL 187-1, and UPAS 120 also showed high grain yield potential under unprotected conditions (892 to 1161 kg ha^{-1}). These lines can be used for developing pigeonpea cultivars with resistance to *H. armigera*.

Evaluation of medium-duration pigeonpea genotypes for stability of resistance to pod borer, *Helicoverpa armigera*: We evaluated 50 pigeonpea genotypes for resistance to *H. armigera* under field conditions. There were two replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 damage rating (DR) scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), egg and larval numbers, and grain yield. The genotypes ICPL 20042, ICPL 20058, ICPL 6, ICPHaRL 4985-4, ICPHaRL 4985-11, and ICPHaRL 4989-7 suffered moderate levels of pod borer damage (DR 4.5 to 5.5). Nineteen lines suffered <40% pod damage, of which ICP 4307-E3, ICPL 20042, ICPB 2047, ICPL 88046, ICPL 96058, and ICPL 332 showed a grain yield potential of 506 to 821 kg ha^{-1} under unprotected conditions.

Evaluation of long-duration pigeonpea genotypes for stability of resistance to pod borer, *Helicoverpa armigera*: We evaluated 31 long-duration pigeonpea genotypes for resistance to *H. armigera* under field conditions. There were two replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 damage rating (DR) scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), egg and larval numbers, and grain yield. The genotypes ICP 3615, ICP 11181, and ICPL 332 suffered moderate levels of pod borer damage (DR 5.5 to 6.0). The genotypes ICP 3615, ICP 8595-E1-EB, ICP 8688, ICP 12150-1, and NP (WR)-15 suffered <20% pod damage compared to 45% in ICPL 87119, and showed a grain yield potential of 520 to 809 kg ha^{-1} under unprotected conditions.

International pigeonpea pod borer, *Helicoverpa armigera* resistance screening nursery: We evaluated 25 genotypes for resistance to *H. armigera* under field conditions. There were three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 rating scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), insect numbers, and grain yield. The genotypes ICP 10351, ICPHaRL 4985-4, ICPHaRL 4989-7, ICPL 20036, ICPL 20062, ICPL 85063, and PPE 45-2 exhibited moderate levels of resistance to pod borer, *H. armigera* damage rating <5.0 at the poding and maturity stages.

HC Sharma

Output target 2009 6.1.1 GN 10-15 new high yielding lines with resistance to diseases and quality and adaptation traits identified and made available to NARS

Achievement of Output Target:
100%

Participating Countries:
Argentina, East Timor, Eritrea, Ghana, India, Kenya, Philippines, South Africa, UAE, USA, Uzbekistan and Vietnam

Participating Partners:
Catholic Univ. Cordoba, Argentina; MAP, East Timor; NARI, Eritrea; PGRI, Ghana; ICAR, India; KARI and Egerton Univ., Kenya; BARI, Philippines; Department of Agriculture, South Africa; ICBA, UAE; Univ. of Georgia, USA; ICARDA, Uzbekistan; and Nong Lam Univ., Vietnam

Progress/Results:
International trials
Six new series of international trials were constituted and multiplied in 2009 rainy season for distribution to collaborators at ICRISAT centre, Patancheru, India as indicated below:
1. Twelfth International Short-duration Groundnut Varietal Trial (XII ISGVT)
2. Twelfth International Medium-duration Groundnut Varietal Trial (SB) [XII IMGVT(SB)]
3. Twelfth International Medium-duration Groundnut Varietal Trial (VB) [XII IMGVT(VB)]
4. Twelfth International Foliar Diseases Resistant Groundnut Varietal Trial (XII IFDRGVT)
5. Twelfth International Confectionery Groundnut Varietal Trial (XII ICGVT)
6. Eighth International Drought Resistant Groundnut Varietal Trial (VIII IDRGVT)

Varietal releases
ICGV 91114, a short-duration drought tolerant variety developed by ICRISAT, was released on 29 June 2009 by State Seeds Sub-committee for Karnataka state in India. This variety was already released
in Andhra Pradesh and Orissa states earlier. Large seeded confectionery variety, ICGV 86564, was released in Philippines as NSIC Pn 15.

Breeder Seed
A total of 31.35 tons of breeder seed of five varieties (ICGV 91114, ICGV 86564, ICGS 76, ICGS 44, and DRG 12) was produced during postrainy 2008/09 and rainy 2009 of which 29.18 tons was distributed to different public and private seed producing agencies for further seed production. Small samples of 2-3 kg were also distributed to 54 farmers on request.

In addition to the above, seeds of different varieties was provided to various partners as per below:
*   Seeds of 19 sets of international trials sets and 466 advanced breeding lines were provided to cooperators in 12 countries.
*   Under ISOPOM project 1000 kg of seeds of ICGV 91114 was supplied to OUA&T, Orissa for seed multiplication.
*   Seeds of three varieties (ICGV 91114, ICGV 76, ICGS 44) were provided to five collaborators under IFAD project to conduct on-farm trial during rainy 2009. ICGV 91114 was provided to OTELP (2500 kg), RDT (2200 kg) and JTDS (600 kg), while seed of ICGS 76 was provided to CTDP (1000 kg), BAU (200 kg) and OTELP (60 kg), and seed of ICGS 44 was provided to OTELP (60 kg).
*   As part of TL II project seeds of varieties ICGV 87846 (2000 kg), ICGV 00351 (300 kg) and ICGV 907115 (30 kg) to TNAU and ICGV 91114 (200 kg) and ICGV 00350 (400 kg) were produced and supplied to our UAS collaborators for conducting on-farm trials and further evaluation.

- Four seed companies (Ajeet Seeds Limited, Chittegaon; Akshay Seed Technology Company, Junagadh; Krishidhan Seeds Limited, Jalna; Nimbkar Seeds Private Limited, Phaltan) have become members of Seed Consortium and seed was supplied to two companies.

Special Project Funding:
ISOPOM, IFAD, TL II and The OPEC Fund

<div style="text-align:right">SN Nigam</div>

Output target 2009 6.1.1 CP 15-20 new high yielding FW resistant desi and kabuli chickpea breeding lines made available to NARS

Achievement of Output Target:
100%

Partner countries:
Australia, Bangladesh, Ethiopia, India, Myanmar, Nepal, Pakistan and South Africa

Partner Institutions:
NARS in the above countries

Special Project Funding:
None

Progress/Results
International chickpea screening nurseries (ICSNs) of desi and kabuli chickpeas: Sixty-two sets of International Chickpea Screening Nurseries (ICSNs), 31 each in ICSN-Desi and ICSN-Kabuli, were distributed to NARS partners across 8 countries for evaluation during 2008/09. Each ICSN consisted of 18 entries and 2 checks – one common check (JG 11 in ICSN-Desi and KAK 2 in ICSN-Kabuli) and one local check. One set of ICSN-Desi and ICSN-Kabuli was evaluated at ICRISAT, Patancheru. The entries were evaluated in a Randomized Complete Block Design (RCBD) with 2 replications. In ICSN-Desi (at Patancheru), ICCV 07112 was the best entry with about 5% yield advantage over the best check (ICCC 37) which yielded 2721 kg/ha**.** In ICSN-Kabuli, ICCV 08305 (2625 kg/ha), ICCV 7303 (2610 kg/ha) and ICCV 08307 (2605 kg/ha) were at par with the best check KAK 2 in terms of yield and resistance to fusarium wilt.

The data received from different locations (22) in India revealed that in ICSN-Desi, ICCV 08109 (2091 kg/ha), ICCV 08108 (1971 kg/ha) and ICCV 08110 (1938 kg/ha) out-yielded the common check JG 11 (1930 kg/ha) while in case of ICSN-Kabuli, ICCV 08307 (1667 kg/ha), ICCV 08312 (1606 kg/ha), ICCV 08311 (1583 kg/ha) and ICCV 08305 (1570 kg/ha) were superior to the common check KAK 2 which yielded 1566 kg/ha.

<div style="text-align:right">PM Gaur, Shailesh Tripathi, CLL Gowda,
Suresh Pande and Mamta Sharma</div>

Development and evaluation of improved breeding lines of desi and kabuli chickpea: Replicated yield trials (9 Preliminary yield trials and 2 Advanced yield trials) were conducted with 69 desi and 129 kabuli entries during 2008-09. In PYTs - Desi, 5 entries (ICCX-030034-F4-P6-BP-BP, ICCX-030034-F4-P4-BP-BP, ICCX-030034-F4-P11-BP-BP, ICCX-030037-F4-P13-BP-BP and ICCX-030034-F4-P15-BP-BP) out yielded the best check. In AYT – Desi, two entries (ICCX-030011-F4-P2-BP-BP and ICCX-030035-F4-P18-BP-BP) were superior to the best check JG 11 (2635 kg/ha).

In PYTs – Kabuli, 13 entries (ICCX-030177-F4--P4-BP-BP, ICCX-030141-F4-P13-BP-BP, ICCX-030155-F4--P2-BP-BP, ICCX-030155-F4--P3-BP-BP, ICCX-030141-F4--P15-BP-BP, ICCX-030155-F4--P10-BP-BP, ICCX-030163-F4--P16-BP-BP, ICCX-030185-F4--P7-BP-BP, ICCX-030185-F4--P12-BP-BP, ICCX-030177-F4--P19-BP-BP, ICCX-030163-F4--P21-BP-BP, ICCX-030147-F4--P2-BP-BP and ICCX-030160-F4--P3-BP-BP) were found promising as compared to the best check, in terms of yield and resistance to FW with 100-seed weight more than 40g. In AYT – Kabuli, 6 entries (ICCX-030185-F4--P2-BP-BP, ICCX-030141-F4--P5-BP-BP, ICCX-030163-F4-P18-BP-BP, ICCX-030163-F4-P32-BP-BP, ICCX-030133-F4--P6-BP-BP and ICCX-030201-F4-P3-BP-BP) were superior to the best check KAK 2 in terms of yield (>1894 kg/ha), resistance to wilt and seed size (100-seed weight > 35g).

<div style="text-align:right">PM Gaur, Shailesh Tripathi and CLL Gowda</div>

Output target 2009 6.1.1 PP 25-30 pigeonpea lines tested multilocationally for their stability to wilt and sterility mosaic resistance in India

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
18 NARS Research Stations in India

Progress/Results:
Identification of stable sources of resistance to Fusarium wilt and sterility mosaic disease
To identify stable and broad based resistance to fusarium wilt (FW) and sterility mosaic disease (SMD), pigeonpea lines having combined resistance to FW and SMD identified at ICRISAT-Patancheru were evaluated for resistance to both these disease at different locations in India through pigeonpea wilt and sterility mosaic disease nursery (PWSMDN). PWSMDN consisted of 30 entries, 28 entries were resistant to both wilt and SMD at ICRISAT-Patancheru and the other two were wilt susceptible (ICP 2376) and SMD susceptible (ICP 8863) checks. Additionally, two local susceptible checks, one for wilt and the other for SMD were also included from the participating location. The nursery was evaluated at 19 locations (Akola, Badnapur, Bangalore, Berhampore, Coimbatore, Dholi, Faizabad, Gulbarga, Hazaribag, ICRISAT-Patancheru, Kanpur, Khargone, Vamban (Pudukottai), Raipur, Rahuri, Sehore, S K Nagar, Vadodara (Gujarat) and Varanasi) in India. In most of the locations the nursery was planted in wilt sick plot and inoculated every plants of the nursery with SMD infested pigeonpea leaves using leaf staple technique at two leaf stage wherever possible and if not, SMD infested twigs were spread on the plants of

the nursery at seedling stage for SMD development. Data on FW and SMD was recorded twice, at flowering and at maturity stages of the crop.

Data on wilt was received from 11 locations (Badnapur, Bangalore, Dholi, Gulbarga, Kanpur, ICRISAT-Patancheru, Khargone, Rahuri, Sehore, Vadodara and Vamban). Of the 28 entries, one entry (ICPL 20096) was found asymptomatic/ resistant (<10.0% incidence) in all eleven locations, two entries (ICPL's 20102 and 20126) were found asymptomatic/ resistant (<10.0% incidence) in ten locations, seven entries (ICP 9174, ICPL's 20098, 20106, 20109, 20116, 20120, and 20129) at nine locations and six entries (ICPL's 20099, 20101, 20110, 20115, 20128 and 20132) at eight locations and eight entries (KPBR- 80-2-4, ICPL's –20093, 20094, 20100, 20103, 20113, 20114 and 20134) at seven locations were found asymptomatic/ resistant to wilt.

Data on SMD was received from nine locations (Badnapur, Bangalore, Coimbatore, Dholi, ICRISAT-Patancheru, Rahuri, Vadodara, Vamban and Varanasi). In Vadodara in local susceptible check (ICP 8863), no incidence of SMD was recorded, hence data was not compiled. Of the 28 entries, two entries (ICPL 20094 and KPBR-80-2-4) were found asymtomatic/ resistant (<10% incidence) at five locations. Nine entries were found asymptomatic/ resistant at four locations (ICP 9174, ICP 12749, ICP 14819, 20096, 20098, 20099, 20106, 20107 and 20115) to SMD.

Special Project Funding:
None

<div align="right">Suresh Pande and Mamta Sharma</div>

Output target 2009 6.1.2 CP 20-30 sources of resistance to FW, BGM, and AB tested for stability across locations and pathotypes in Asia

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
23 NARS Research Stations in India

Special Project Funding:
None

Progress/Results:
Evaluation of Chickpea Wilt and Root Rot Nursery (CWRRN) for resistance to FW: Chickpea wilt and root rot nursery (CWRRN) consisted of 30 entries (28 wilt resistant +2 wilt susceptible cultivars) was evaluated at 24 locations (Akola, Badnapur, Bangalore, Berhampore, Coimbatore, Dhaulakuan, Dharwad, Dholi, Faizabad, Gulbarga, Hazribagh (CRUUS, HCKVK), Hisar, ICRISAT-Patancheru, Jabalpur, Junagadh, Kanpur, Ludhiana, New Delhi, Pantnagar, Rahuri, Raipur, Sehore and Varanasi) in India during 2008/09 season. Data on wilt was recorded thrice at seedling, flowering and at maturity stages of the crop.

Data from fifteen locations (Bangalore, Berhampore, Dharwad, Dhaulakuan, Dholi, Gulbarga, ICRISAT-Patancheru, Jabalpur, Junagadh, Kanpur, Ludhiana, New Delhi, Pantnagar, Rahuri and Sehore) was received and compiled. One entry, ICCV 05528 was found asymptomatic to resistant in eight locations. One entry (ICCV 05527) in six locations, three entries (ICC 14386, ICCVs 96818 & 05529) in five locations, four entries (ICCs 11324, 14364, ICCVs 04113 & 04312) in four locations; seven entries (ICC 11322, ICCVs 92311, 92337, 96851, 05107, 05310, 06106) in three locations were found asymptomatic to resistant to wilt. Four entries ICCVs 96818, 04107, 04108 and 06106 were moderately resistant to wilt in six locations in the current season.

Evaluation of International Ascochyta Blight Nursery for resistance to AB: International Ascochyta Blight Nursery (IABN) consisted of 30 entries of which 28 were moderately resistant to AB and two susceptible checks including local check of the respective location. IABN was evaluated under field conditions at six locations (Almora, Dhaulakuan, Gurdaspur, Hisar, ICRISAT-Patancheru and Ludhiana) in India and one location in Pakistan. The nursery was inoculated with conidial suspension of *A. rabiei* @ 50000 conidia ml^{-1}, two-three times at flowering stage of the crop at weekly intervals (depending on the AB severity) in all the locations. Evaluation at ICRISAT-Patancheru was done under controlled environment following standardized whole plant screening technique.

Data was received from five locations except Hisar. Susceptible cultivar ICC 4991 showed highly susceptible reaction (9 rating on 1-9 scale) in all the five locations in India. Two entries, ECs516934, 516971 in five locations and eleven entries, ICCs 607, 4181, ICCVs 04537, 98818, ECs 517003, 516792, 516867, 516967, 517011, 517023, 517039 in four locations were found resistant (≤3.0 rating) to AB. Fifteen entries were found resistant to moderately resistant to AB in all the five locations in India. However, 17 entries were found moderately resistant to AB at all the six locations.

Evaluation of International Botrytis Gray Mold Nursery for resistance to AB: International Botrytis Gray Mold Nursery (IBGMN) consisted of 30 entries of which 28 were BGM promising entries identified under controlled environment at ICRISAT-Patancheru and one susceptible check (ICC 4954). One local susceptible check of respective location was also added. IBGMN was evaluated at four locations in India (Gurdaspur, Ludhiana, ICRISAT-Patancheru and Pantnagar), one location in Nepal (Nepalgunj). All the entries of the nursery were artificially inoculated with conidial suspension of the local isolate of *Botrytis cinerea* at flowering and pod initiation stage of the crop in all the locations. At ICRISAT- Patancheru the nursery was evaluated under controlled environment conditions following standardized whole plant screening technique.

Data was received from all the four locations in India and one location from Nepal. Susceptible checks showed highly susceptible reaction (9 rating on 1-9 scale) in all the locations. High level of resistance was not observed in any of the entries tested in all locations. However, two entries ICCVs 04609, 05604 in four locations, ten entries in three locations and nine entries in two locations were found resistant to moderately resistant (< 5.0 rating) to BGM.

<div align="right">Suresh Pande, Mamta Sharma, PM Gaur, Shailesh Tripathi,
CLL Gowda and Collaborators</div>

Purification and maintenance of virulence of pathotypes of *Fusarium oxysporum* f.sp. *ciceris*: One hundred and forty two isolates of *Fusarium oxysporum* f.sp. *ciceris* (FOC) collected from 20 locations in 13 states in India were purified for the cultural, morphological and molecular variability studies. Pathogenicity test and Koch's postulates were proved using a common susceptible cultivar JG 62 following standardized evaluation technique under greenhouse conditions at ICRISAT-Patancheru. Single spore isolates were obtained following standardized mycological techniques.

Purification and maintenance of virulence of pathotypes of *Ascochyta rabiei*: A total of 37 isolates of *Ascochyta rabiei* collected from 14 locations in six states in India were purified. Pathogenicity and Koch's postulates of all these isolates were proved using a common cultivar Pb 7 following standardized evaluation protocol under controlled environment conditions. Cultures were single spored following standard mycological techniques.

Purification and maintenance of virulence of pathotypes of *Botrytis cinerea*: A total of 42 isolates of *Botrytis cinerea* collected from 13 locations in eight states in India and 10 locations in Nepal were purified. Pathogenicity and Koch's postulates of all these isolates were proved using a common cultivar JG62/H208 following standardized evaluation protocol under controlled environment conditions. Pure cultures were selected and single spored following standard mycological techniques.

<div align="right">Suresh Pande and Mamta Sharma</div>

Output 6.2: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of legume mandate crops and associated capacity building made available to partners internationally

Output target 2009 6.2.1 GN 6-8 dual purpose groundnut varieties with high biomass and improved haulm digestibility identified and promoted for drought prone areas in Asia (collaboration with ILRI)

Achievement of Output Target:
75%
The results of fodder quality analysis are awaited from ILRI.

Participating Countries:
India

Participating Partners:
ICAR and SAUs

Progress/Results:
Groundnut haulm samples of IVT-1 (SB) trial of AICRP-G from Tamil Nadu (Virdhachalam), Karnataka (Dharwad), Maharashtra (Jalgaon) and Gujarat (Junagadh) were received and handed over to ILRI for fodder quality analysis.

Special Project Funding:
ISOPOM, IFAD, TL II and The OPEC Fund

<div align="right">SN Nigam</div>

Output target 2009 6.2.1 CP QTLs for drought avoidance root traits validated

Achievement of Output Target:
100%

Participating Countries:
None

Comments/Explanations:

Participating Partners:
None

Progress/Results:
As reported in 2008, based on extensive phenotyping and SSR genotyping of a RIL population (ICC 4958 × ICC 1882), one genomic region (35 cM) harbouring QTLs for several drought related traits measured in two environments has been identified in Phase I of TL-I (Fig. 6.1). In order to validate the QTL for drought avoidance related root traits, the markers in the QTL region namely GA24, TAA170, ICCM0249 and STMS11were genotyped on a set of 30 farmers preferred genotypes from Kenya, Ethiopia and Kanpur. However based on screening of farmers preferred genotypes and ICC 4958 for these 4 markers, majority of times appropriate polymorphisms was not observed (Table RKV 6.1). Nevertheless, two crosses each region was selected for introgression of these QTL into farmer preferred cultivars. Further under TL-I, Phase I, using ICC 4958 as donar, introgression of these QTL regions into JG 11 background is underway.
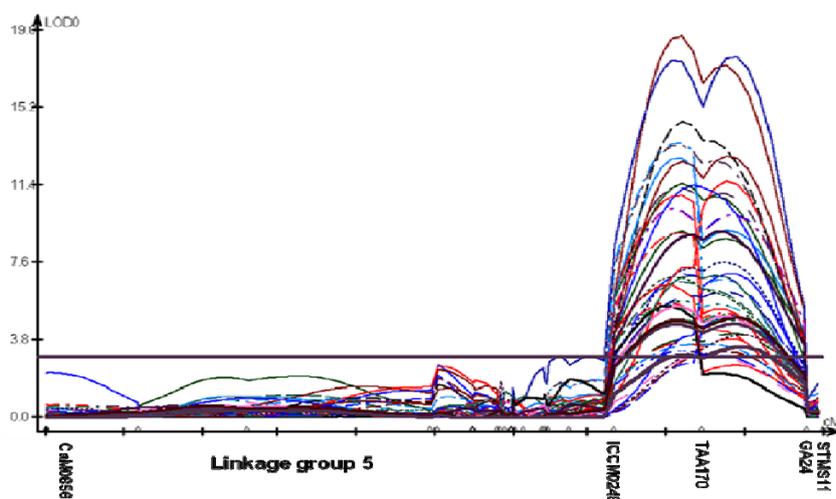
Figure 6.1. A genomic region hotspot identified on linkage group 5 that harbors QTLs for several drought-related physiological traits

RK Varshney, SN Nayak, T Mahendar, PM Gaur,
V Vadez and L Krishnamurthy

Output target 2009 6.2.2 GN Three transgenic DREBIA events with drought resistance identified

Achievement of Output Target:
100%

Participating Countries:
None

Participating Partners:
None

Progress/Results:

We assessed the putative role of a transcription factor, *DREB1A* driven by a stress inducible *rd29A* promoter both from *Arabidopsis thaliana*, on transpiration efficiency (TE) and water extraction from lysimeters (long and large PVC tubes filled with soil and mimicking a real soil profile). Our approach was to thoroughly assess whether transgenic DREB1A event derived from wild type variety JL24, which is known for its relative drought sensitivity, would have increased values in traits putatively related to a better yield under stress conditions, prior to assess a yield response *per se*. The yield under both terminal and intermittent stress conditions was assessed in two separate experiments, using selected events. Transpiration efficiency was assessed during several experiments and several events were consistently found having higher TE that JL24, i.e. RD2 and RD33. These promising DREB1A events when compared with breeding materials also known to have large TE were found to be at par or above. The selected events were advanced to T5 and T6 generation, and further evaluated for their water capturing capacity and yield response under water stress conditions in a lysimetric system, i.e. PVC tubes of 1.2 m and 20 cm diameters, filled with soil and weighable. We found that all events had similar volume of water used and pattern of water extraction under well watered conditions, which were related to similar pattern of root development in the soil profile. However, under the influence of drought stress, the water uptake in several events was up to 30% higher than in JL24, and this was related to a larger root development in the transgenics at all depths.

In a first yield response experiment, where a terminal drought was imposed, i.e. irrigation suppressed at 40 days after sowing, none of the transgenics had higher yield than the wild type under water stress, although 2 events had 16 and 23% higher yield under well-watered conditions. In a second experiment, where an intermittent stress was imposed by re-watering 1L water to drought stress plants at 6, 9, and 12 weeks after stress imposition, 3 transgenics had a yield about 30-40% higher yield than the wild type, whereas there was no significant differences under well-watered conditions. Efforts are ongoing to confirm these observations, along with breeding efforts to cross most promising events with superior breeding material and test the value of introgressing DREB1A into different genetic backgrounds.

The first contained field strip trial was carried out under nethouse for the evaluation of yield in the six selected transgenic events (RD2, RD11, RD12, RD19, RD20 and RD33) carrying the *DREB1A* gene driven by the stress-responsive *rd29A* gene promoter, under intermittent drought conditions. T7 generation seeds from the above mentioned six transgenic events along with JL24 null and an additional breeding line ICGV 86031 were planted in the lysimeters (PVC cylinders measuring 1.2 m length and 20 cms diameter). Two seeds per cylinder with two treatment sets (DS and WW) having nine replicates each were planted on 18th January 2009 and grown with periodic watering for around 40 days till flowering. Saturation of the soil profile was followed by regular weighing of the cylinders once a week basis. WW plants were maintained at near field capacity water status, while intermittent stress was imposed on DS plants by re-watering 1500 ml at 29, 46, 51, 57, 69 days after saturation in the outdoor trial. After completion of the trial harvested crop from the experiment was separated into leaf, stem and pod fractions. Dry weights of stem, leaf and pod were measured after drying at 80°C in a hot air oven for 48 to 72 h. Results indicated that under well watered (WW) conditions all other transgenic events along with JL24 and ICGV86031 had similar TE. Yield coefficient under WW conditions was found to be significantly lower in RD11 than JL24, while rest were similar. A very high correlation

was found between Transpiration efficiency, Biomass accumulated, cumulative transpiration and Pod weight under well watered conditions. TE was also well correlated with Harvest Index, but the later had no relationship with Biomass and cumulative transpiration.

Under drought stress (DS), yield in terms of pod and seed dry weight was found to be significantly higher in the transgenic event RD11 compared to other transgenic events as well as the controls i.e., JL24, Null and ICGV 86031. Besides, event RD33 closely followed RD11 with its seed weight being significantly higher than JL24 under drought stress. Both the events had highest Harvest Index, that was significantly higher than control JL24. While the pod and seed yields in both the tested transgenic events was higher, RD33 also showed significant increase in accumulation of leaf, shoot and biomass than RD11, which interestingly had lowest, leaf and shoot dry weight. Transpiration Efficiency (TE) did not correlate with pod yield, HI and cumulative transpiration under stress. However, a high correlation was found between Total Biomass accumulation and Transpiration Efficiency. The results indicated that these events showed promise for yield under intermittent drought conditions. These results were quite encouraging and another strip trial has been planned for Jan 2010 for validating these results.

Table 2. Sum of transpired water in the 0-28 days, 28-42 days and 0-42 days after treatment.

	Water transpired		
	0-28 d after treatment	28-42 d after treatment	0-42 d after treatment
Water stress			
JL 24	4678 ± 105	1738 ± 52	6416 ± 152
RD 2	5452 ± 114	1778 ± 40	7230 ± 87
RD 11	5177 ± 31	1728 ± 121	6905 ± 136
RD 12	4760 ± 182	1566 ± 220	6326 ± 246
RD 19	5138 ± 95	1632 ± 212	6770 ± 208
RD 20	4722 ± 117	1870 ± 85	6592 ± 85
RD 33	5343 ± 92	1692 ± 76	7035 ± 85
Well-watered			
JL 24	7597 ± 358	6738 ± 330	14335 ± 527
RD 2	8400 ± 204	7670 ± 363	16070 ± 534
RD 11	7162 ± 210	5290 ± 438	12452 ± 637
RD 12	6778 ± 206	5818 ± 368	12596 ± 461
RD 19	7175 ± 476	6193 ± 364	13368 ± 814
RD 20	7196 ± 273	6562 ± 328	13758 ± 588
RD 33	8372 ± 444	7732 ± 443	16103 ± 814

Table 3. Seed yield and biomass (g plant^{-1}) in three yield assessment experiments under terminal (Exp1) and intermittent (Exp 2 and 3) stress, along with a well-watered control

	Exp 1		Exp 2		Exp 3	
	Seed weight	Biomass	Seed weight	Biomass	Seed weight	Biomass
Stress	**Terminal**		**Intermittent (Glasshouse)**		**Intermittent (outdoors)**	
JL 24	8.75 ± 0.39	29.36 ± 1.19	6.02 ± 1.86	37.70 ±2.34	4.18 ± 0.62	36.22 ±0.55
RD 2	8.71 ± 0.72	31.09 ± 1.60	11.66 ± 1.27	44.74 ±1.60	3.69 ± 0.44	30.38 ±1.34
RD 11	7.44± 0.49	26.21± 1.87	9.89 ± 1.09	38.11 ±1.44	6.37 ± 0.65	31.36 ±0.93
RD 12	6.05 ± 0.30	25.83 ± 2.46	7.59 ± 1.68	43.84 ±2.06	2.00 ± 0.31	32.65 ±0.97
RD 19	5.67 ± 0.87	25.26 ± 1.78	10.69 ± 0.79	39.75 ±1.12	4.58 ± 0.32	31.30 ±0.64
RD 20	6.48 ± 0.51	30.05 ± 1.52	8.06 ± 1.42	41.29 ±3.37	3.70 ± 0.32	38.50 ±0.63
RD 33	5.06 ± 0.62	36.90 ± 2.62	7.11 ± 1.96	41.09 ±5.55	6.17 ± 0.28	35.99 ±1.06
Null					4.40 ± 0.45	34.30 ±0.67
ICGV 86031					3.34 ± 0.20	32.74 ±0.36
	Well-watered					
JL 24	10.81 ± 2.61	40.92 ± 5.91	37.63 ± 2.83	132.74±8.52	10.88 ±2.28	50.12 ±6.08
RD 2	15.12 ± 1.80	58.94 ± 6.48	35.48 ± 3.67	117.49±9.46	16.84 ±1.01	57.55 ±3.48
RD 11	12.93 ± 2.41	47.64 ± 5.70	28.90 ± 3.57	93.18±11.63	10.35 ±1.26	46.78 ±2.71
RD 12	10.26 ± 4.43	42.89 ±15.99	34.29 ± 3.01	115.58±6.63	10.64 ±1.55	43.47 ±4.14
RD 19	8.38 ± 2.46	38.12 ± 9.03	21.71 ± 2.25	71.39 ±8.30	12.03 ±1.06	57.38 ±2.31
RD 20	12.58 ± 2.64	52.84 ± 9.89	36.66 ± 2.60	131.95±10.32	18.98 ±1.80	70.01 ±2.86
RD 33	15.66 ± 2.47	87.15 ± 10.38	27.86 ± 3.72	117.55±12.41	18.74 ±1.33	69.09 ±2.22
Null					8.05 ± 1.68	28.47 ±3.49
ICGV 86031					18.15 ±0.87	65.45 ±1.39

Output target 2009 6.2.1 PP A set of pigeonpea genotypes suitable to breed for salinity tolerance identified

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
None

Progress/Results:

A large screening of 300 accessions of pigeonpea has been performed. These 300 accessions the materials were 150 genotypes of the mini core collection maintained by genetic resource unit at ICRISAT, 68 different wild accessions, 69 accessions selected from salinity prone areas worldwide (Bangladesh, Taiwan, Ethiopia, Indonesia, Argentina, Iran, and Brazil), and 13 genotypes from breeding material (breeding lines and cytoplasmic male sterile lines; derivatives of different wild species), and a few pigeonpea hybrids. The first trial was performed under rainout shelter to avoid rains in alpha lattice design (30X10) in three replications with two treatments (0.88 g NaCl / kg of Alfisol and control). The soil was fertilized with DAP and also treated with carbofuran to prevent fungal and trips infestation in soil. The stressed pots were also treated as above, with saline solutions such that the overall 0.88 g/kg were divided into three split doses. The field capacity of pots was maintained throughout the experiment. The experiment was harvested at 70 days after sowing.

In pigeonpea, because the evaluation for salinity tolerance was based on the biomass under salt stress and control, we assessed salinity tolerance based on the percent relative reduction under saline conditions compare to control and the salinity susceptibility index by using the formula $SSI= (1-Y_{SS}/Y_{NS})/SII$, where Y_{SS} and Y_{NS} are the mean biomass of a given accession in saline and non saline conditions respectively. SII is the salinity intensity index, was calculated as $SII=1-X_{SS}/X_{NS}$, where X_{SS} and X_{NS} are the mean of all accessions under salinity stressed and non- stressed environments (Fisher and Maurer, 1978). The genotypes with less than 50 % relative reduction and with their SSI values ranging between 0-0.75 were considered as tolerant. The genotypes which were having relative reduction more than 50% and less than 70% and SSI values ranged between 0.76-1.05, assumed as moderately tolerant and those which had relative reduction ranged between 70-90% and SSI values 1.06-1.37 considered as moderately susceptible. The genotypes with more than 90% relative reduction in biomass and SII ranged between 1.38-1.52 assumed as highly susceptible.

In pigeonpea, we found very large range of variation for percent relative reduction in biomass (2-100%) among wild relatives. Among the wild accessions, ICPW 87 and ICPW 94 were most tolerant to salinity with SSI value 0.03 and 0.28 and their relative biomass reduction was very small (2.0 and 18.6%). Both genotypes belong to the *C. scaraboides*. One accession (ICPW 68) of *C. platycarpus* had also low SSI value 0.37 and only 24.3% of relative reduction in biomass. For the accessions selected from different areas putatively being affected by salinity the variation ranged from 42-100% for relative reduction in biomass and 0.64 to 1.52 for SSI values, which also show a very large genotypic variation to identify contrasting entries for salinity tolerance. In this set ICP 13991, 14974, 13997, and 11412 were tolerant and ICP 13625, 13996, 14175, 11414 and 11420 showed high susceptibility. Among the mini-core collection of pigeonpea the range of variation for biomass relative reduction was 15-100% and for SSI it ranged between 0.23-1.52. These data show that the mini-core collection contained genotypes having higher salinity tolerance than in the group of genotypes putatively originating from salinity-affected areas. Out of 150 genotypes of mini core 13 were considered as tolerant *viz* ICP 8860, 7803, 7260, 6815,10654,3046, 2746,7426,10559, 7057, 6049, 6859 and ICP 7 and four ICP 15493, 15382, 1071 and 6739 were considered salinity susceptible based on their SSI and percent relative reduction in biomass. Finally, for the set of wild derivatives of pigeonpea the range varied between 42-84% biomass reduction and their SSI values 0.75-1.52. Out of them ICPB 2051, 2030 and 2039 were tolerant and ICPB 2032 was highly susceptible.

V Vadez and L Krishnamurthy

Output target 2009 6.2.1 SO Five sorghum varieties with salinity tolerance developed

Achievement of Output Target:
75%
The advanced breeding progenies were screened simultaneously at ICRISAT under normal conditions and ARS, Gangavathi under saline conditions. The selected stabilized progenies are being evaluated in preliminary trials and they need to be further evaluated for confirmation of the results.

Participating Countries:
India

Participating Partners:
Indian NARS (Public sector), ICRISAT & ICBA

Progress/Results:
The promising salinity tolerant F_6 progenies were evaluated in two replicated trials, PCVT and PWVT based on the grain color.

Preliminary cream grain colored varietal trial (PCVT): Newly developed 46 cream grain colored varieties were evaluated in PCVT during 2009 rainy season along with the checks SPV 1616, SPV 475, M 35-1 and ICSB 52. Compared to the best performing check SPV 1616 (2.3 t ha^{-1}), three varieties, SP 25856-1 (2.8 t ha^{-1}), SP 25765-1 (2.6 t ha^{-1}) and SP 25640-1 (2.4 t ha^{-1}) were significantly superior for grain yield and 22 varieties with the grain yield ranging from 1.7 to 2.2 t ha-1 were comparable to it. The grain mold score in the selected lines ranged from 2.0 to 4.0 (SPV 1616: 3.0). The variety, SP 25831-1 was most tolerant to grain mold with a score of 2.0 (grain yield: 1.9 t ha^{-1}, days to 50% flowering: 69 days and plant height: 1.8m).

Preliminary white grain colored varietal trial (PWVT): Newly developed 64 white grain colored varieties were evaluated in PWVT during 2009 rainy season along with the checks SPV 1616, SPV 475, M 35-1 and ICSB 52. Compared to the best performing check SPV 475 (1.8 t ha^{-1}), 18 varieties with a grain yield ranging from 2.2 to 3.0 t ha^{-1} were significantly superior. The grain mold score in the selected lines ranged from 2.0 to 4.0 (SPV 475: 2.7). The variety, SP 25638-1 was most tolerant to grain mold with a score of 2.0 (grain yield: 2.3 t ha^{-1}, days to 50% flowering: 72 days and plant height: 1.9 m).

BVS Reddy, A Ashok Kumar and Vincent Vadez

Output 6.3: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification breeding, improved germplasm of pearl millet, sorghum, groundnut and pigeonpea crops and associated capacity building made available to partners internationally

Output target 2009 6.3.1 FORT Pigeonpea psy1 events with beta-carotene identified

Achievement of Output Target:
75 %
Although on the basis of the available carotenoid data generated so far, we were able to identify some promising transgenic events carrying enhanced levels of ß-carotene. However, since the transgenic events are still in early generations and are segregating for the transgene, these results need to be validated in subsequent generations. Moreover, additional events are being developed with both maize *psy1* and tamato *ßlyc* genes, that might have higher levels of these desired carotenoids.

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:

Agrobacterium-mediated genetic transformation was previously carried out using the binary vectors containing maize *psy*1 gene driven by oleosin promoter for generating pigeonpea transgenic events with enhanced level of ß-carotene. 140 putative transgenic plants with maize *psy*1 have been transferred to the containment greenhouse and were characterized at molecular level for the integration and expression of the transgenes. Total carotenoids in the primary T_0 putative pigeonpea plants were estimated spectrophotometrically and 11 events selected for further analysis. These events showed 2 to 3-fold increase in ß-carotene levels evidenced using HPLC analysis.

Over 60 transgenic events were advanced to T1 generation and subjected to molecular analysis. Seeds were collected from T_1 generation plants and subjected to HPLC analyses for ß-carotene content of seed samples. Studies indicate that the transgenics had much higher lutein content over the controls amongst the individual carotenoids. Since, *ß-lycopene cyclase* (*BLYC*) is the key enzyme involved in ß-carotene synthesis pathway, we assume that gene pyramiding with psy1 and *BLYC* may result in much higher accumulation of ß-carotene. Development of newer marker free pigeonpea transgenic plants carrying both maize *psy1* and tamato *ßlyc* genes was initiated by using binary vector pZP200.Ole:PSY::35S:*BLYC*, to meet the target levels of provitamin A.

Special Project Funding:
No funding available during 2009

<div align="right">Pooja Bhatnagar-Mathur, KK Sharma and KB Saxena</div>

Output target 2009 6.3.4 DTOX 8-10 elite aflatoxin resistant lines identified and made available to NARS

Achievement of Output Target:
100%

Participating Countries:
India, Kenya, USA

Participating Partners:
ICAR, KARI, UG

Special Project Funding:
ISOPOM, IFAD, TL II and The OPEC Fund

Progress/Results:
International aflatoxin resistant groundnut varietal trial

One set of international aflatoxin resistant groundnut varietal trial seeds to Kenya and 45 advanced breeding lines and 5 segregating populations were made available to India and USA.

New crosses
Ten new crosses were made in the 2008/09 postrainy and 2009 rainy seasons to develop aflatoxin tolerant breeding lines. New breeding lines, ICGV # 94434, 99195, 07043, 06118, 91300, 08047, 08112, 07165, 07173 and 07193 were used as sources of resistance to aflatoxin in hybridization program.

Breeding populations
In the 2008/09 postrainy season, 148 F_2-F_{11} bulks and 349 plant progenies were sown for further selection. From these, 193 bulk and 79 single plant selections were made. Of these, 45 bulks in advanced generations were identified for inclusion in replicated yield trials. The promising selections for agronomic traits came from (ICGV 93280 x ICGV 99159), (PI 337394F x AH 7223), and (TMV 2 x UF 71513-1) crosses. Similarly in the 2009 rainy season, 272 F_2-F_9 bulks and 79 plant progenies were sown for further selection. From these, 221 bulks and 95 single plant selections were made. The promising selections for agronomic traits came from (ICGV 93280 x ICGV 99159) cross.

Replicated trials
Results of yield trials conducted in the 2008 rainy season (not reported in the 2008 Archival report) 2008/09 post rainy, are discussed here. Seventy-four advanced breeding lines including controls were evaluated under normal growing conditions for yield and other agronomic traits in two replicated trials (Elite Trial and Advanced Trial) in both 2008 rainy and 2008/09 postrainy seasons. In the postrainy season the two trials were also conducted in *A. flavus* sick plots and subjected to end-of-season drought to promote aflatoxin contamination so as to discern genotypic differences for preharvest seed infection and aflatoxin content. The main findings are given below-

2008/09 postrainy season
- In Elite Trial, 11 lines (6.4-5.2 t ha^{-1} pod yield) significantly out-yielded the highest yielding resistant control J 11 (4.1 t ha^{-1} pod yield, 71% shelling outturn, 36 g HSW, 48% oil content, 25 protein content, 0.3% *A. flavus* infection, and 0.7 µg/kg Aflatoxin contamination). ICGV 07170 ranked first in pod yield (6.4 t ha^{-1} pod yield, 63% shelling outturn, 58 g HSW, 55% oil content, and 21% protein, 3.0% *A. flavus* infection, and 42.9 µg/kg Aflatoxin contamination) while ICGV 07156 recorded the lowest A. flavus infection (0.8%) but ranked eleventh in pod yield (5.2 t ha^{-1} pod yield, 73% shelling outturn, 54 g HSW, 48% oil content, 22% protein, 0.8% *A. flavus* infection, and 0.4 µg/kg Aflatoxin contamination).

2009 rainy season
- One hundred and thirty two advanced breeding lines including controls were evaluated for yield and other agronomic traits in three replicated trials. The results of aflatoxin analysis are awaited.

SN Nigam

Evaluation or Reference Collection
Common entries from the groundnut reference collection (n=246) have been tested in a sandy soil in Niger at the ICRISAT Sahelian center (in a trial with 268 entries) in late 2008 (late planting in the rainy season) and early 2009 (summer season) under both fully irrigated conditions and intermittent stress conditions. The fully irrigated treatment received irrigation approximately every 5 days depending on Eto and water application was approximately 30mm at each irrigation. The intermittent stress was applied from about flowering time (35 days after sowing. It consisted roughly in skipping one irrigation in two of the irrigated treatment. Trials were Alpha lattice with 6 replications in Niger (2 row plots, 2-m long).

These trials carried out in Niger were intended to test pod yield under stress and non-stress condition. However, since the Sahelian center location is naturally contaminated with aflatoxin, we have measured aflatoxin contamination in seed samples. This gives us the possibility to test genetic variation and possible interaction with temperature, since trials were carried out both in the hot and the cool season. Data revealed a large range of variation for aflatoxin contamination. This gives the possibility to develop populations that contrast for aflatoxin contamination and opens new opportunities for an issue that is extremely important in groundnut, especially with a view towards MARS (= multi-trait breeding) in groundnut. In addition, it provides good material to start investigating the interactions between aflatoxin contamination and sensitivity to drought.

Falalou Hamidou, Vincent Vadez and Farid Waliyar

Transgenics for aflatoxin resistance
Molecular characterization of the four transgenic events carrying *RChi*t gene that previously showed higher chitinase activity were advanced to subsequent generations and their fungal bioassays were carried out under lab/greenhouse conditions including proper controls JL 24 and J11. In the pre-harvest aflatoxin screening of T5 groundnut transgenics for *A. flavus,* no significant variation was observed between all the four transgenic events and control tested for pre-harvest *A. flavus* infection. However, three out of the four tested events showed significantly lower average aflatoxin content ranging from 516-655 µg/kg as compare to 2501 µg/kg and 2080 µg/kg in JL 24 and J 11 controls, respectively.

These events were also screened for Late leaf Spot (LLS) incidence in detached leaf bioassays. Results indicated significant genotypic differences for LP, LD30 and IF30 (at P<0.001), and for IP, & LN30 (at P<0.05). Although no genotypic differences were found for leaf area damage at 30 days after inoculation (LAD30), disease symptoms began appearing on leaflets of non-transgenic control plants within 13.3 days after inoculation. Event #31 and 44 are showing significantly lower incubation period as compare to non-transgenic control plants. Latent period ranged from 21.8 days to 23.6 days in transgenic plants as compared to 16.3 days in non-transgenic control plants. All events showed higher latent period as compared to non-transgenic control plants. Similarly detached Leaf Bioassay against Rust resulted in significant genotypic differences for LP, PN30, LAD30, and IF30 at (P<0.001) and for IP at (P<0.05). Disease symptoms began appearing on leaflets of non-transgenic control plants within 9.4 days after inoculation. Average incubation period ranged from 9.6 days in Event # 12 to 11.9 days in Event # 31. All transgenic events showed significantly higher incubation period as compare to non-transgenic control plants. All transgenic events showed significantly higher latent period (19.85 days to 24.15 days) as compared to non-transgenic control (14.7 days). All transgenic events are showing significantly lower pustule number (132.2-176.9) as compared to non-transgenic control plants (521.5). Leaf area damage at 30 days after inoculation on transgenic groundnut varied from 2.38 to 3.5% as against 53.5% in non-transgenic control plants.

Besides, micro sick plots have been designed and developed in the field for contained field evaluation of these transgenic events. These micro sick plots have been constructed under a net house according to the biosafety considerations. An application made to carry out strip trials for event selection under field was approved by IBSC/RCGM for Kharif 2009, but couldn't be carried out due to unfavorable season, and now has been planned for Jan 2010.

KK Sharma, Pooja Bhatnagar -Mathur and SN Nigam

Output target 2009 6.3.5 IPM Rural stakeholders trained in biopesticide production and utilization

Achievement of Output Target:
100%

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Farmers (22 in number) from Punjab and Orissa (on 21st Jan 09), 20 officers from NABARD (11th Feb 09), 3 technical officers from Regional Agricultural Research Station, Nepal (16th Feb 09) and a microbiologist from Nirmal seeds Pvt. Ltd. (BRC member; 9th to 12th June 09) had hands on training in biopesticide production and evaluation at ICRISAT.

Special Project Funding:
None

S Gopalakrishnan

Output target 2009 6.3.6 CAP Nucleus/Breeder seed production of ICRISAT-bred advanced breeding lines released in partner countries undertaken on request from NARS

Achievement of Output Target:
100%

Countries Involved:
India, Philippines, Myanmar, China

Partners Involved:
NARS in above countries

Special Project Funding:
ICAR Revolving Fund, ISOPOM, Govt. of India, Tropical Legumes II, IFAD Grant 954

Progress/Results:
Groundnut

2008/09 postrainy season: 29.60 t of Breeder seed of five varieties was produced and 27.43 t distributed to different public and private seed producing agencies for further seed production. Variety wise details are given below:

Table 4: Groundnut breeder seed produced and distributed during 2008/09.

Variety	Area (ha)	Production (kg)	Distribution (kg)
ICGV 91114	13.9	21000	20310
ICGS 44	2.0	4400	3695
ICGS 76	1.0	1800	1695
DRG 12	1.0	1400	1400
ICGV 86564	0.8	1000	325
Total	**18.7**	**29600**	**27425**

2009 rainy season: 1.75 t of Nucleus/Breeder seed of ICGV 91114 was produced for further seed production purpose in the 2009/10 postrainy season.
SN Nigam

Chickpea

Total 22.26 t of Breeder seed of 11 (5 Desi + 6 Kabuli) improved chickpea varieties was produced during the crop season 2008/09. Over 20 t Breeder seed of improved chickpea varieties was distributed to partner institutions involved in special projects, various seed producing agencies and farmers.

Table 5. Chickpea breeder seed produced and distributed during 2008/09.

Variety	Area (ha)	Seed produced (kg)	Seed distribution (kg)
Kabuli			
ICCV 2	8.7	6930	2740
KAK 2	1.9	2550	2495
Vihar	0.6	700	125
JGK 1	0.5	30	-
JGK 2	1.3	1250	480
ICCV 95334	0.7	750	-
Desi			
ICCC 37	4.2	4550	10280
ICCV 10	0.5	450	600
JG 11	1.0	1750	1585
JG 130	1.6	1750	1475
JAKI 9218	2.2	1550	1072
Total	**23.2**	**22260**	**20852**

PM Gaur, CLL Gowda and Shailesh Tripathi

Pigeonpea

During 2008/09 a total of 3160 kg breeder seeds of seven [ICPL 87119 (Asha), ICP 8863 (Maruti), ICPL 88039 (VL Arhar 1), ICP 7035 (Kamica), ICPL 87051, ICPL 96053, and ICPL 85063] pure-line varieties were distributed to various NARS partners from the Philippines (Isabela State University San Mateo, Nueva Vizcaya State University Nueva Vizcaya, Benguet State University Benguet, Mariano Marcos State University Batac City), Myanmar (DAR, Yezin), China (Research Institute of Resources Insects, Kumming, and Organization of Food Crops Research Institute, Yunnan Academy of Agricultural Sciences) and India (ANGRAU, Hyderabad; IARI, New Delhi; IIPR, Kanpur; JNKVV, Jabalpur; MAU, Parbhani; MSSCL, Akola; NSC, New Delhi; PAU, Ludhiana; SFCI; and TNAU, Coimbatore). Farmers from Andhra Pradesh, Maharashtra, Karnataka, and Uttar Pradesh were distributed a total of 480 kg seeds of Asha, Maruti, Lakshmi, VL Arhar 1 and ICP 7035 during 2009.

RK Srivastava and KB Saxena

Output target 2009 6.3.6 CAP Farmers' field days, as and when needed, organized at special project locations

Achievement of Output Target:
100%

Participating Countries:
India, Nepal and Myanmar

Participating Partners:
ANGRAU, Nandyal and Lam, Andhra Pradesh; UAS-Dharwad and Gulbarga, Karnataka and NARS in Nepal and Myanmar

Special Project Funding:
ISOPOM, Govt. of India; IFAD Grant 954, ACIAR legumes project in Myanmar, Gates Foundation, COGGO, NSFM, Govt. of India

Progress/Results:

Chickpea
As part of Tropical Legumes II activities, farmers' field days were organized at project locations in Andhra Pradesh and Karnataka States of India. In Andhra Pradesh, field days and on-farm training programs (on mother-baby trials and seed production) were organized at 5 villages in Kurnool and Prakasam districts, and two farmer-scientists interactions were organized at RARS, Nandyal. Nearly 320 farmers participated in these programs. In Karnataka, field days were organized in 17 villages of Dharwad, Gadag and Gulbarga districts during Jan-Mar 2009. About 2190 farmers participated in these farmer days at the above locations.

Under IFAD and NFSM projects, total 6 exposure visits/training programs were organized at ICRISAT, Patancheru during 2009 in which 111 farmers/Agriculture Officers/project staff from Jharkhand, Uttar Pradesh, Madhya Pradesh and Orissa states of India and 3 Technical Officers from Nepal were made aware about improved chickpea cultivars and seed production technologies.

PM Gaur, CLL Gowda and Shailesh Tripathi

Pigeonpea
A total of five Farmer's Field days/training programs/exposure visits were conducted in India (Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, and Uttrakhand), and one in Myanmar. Farmers were trained in seed production technology, harvesting, processing, and storage. Structured training programs were conducted in integrated pest management technology (IPM), and agronomy. Under various special projects, training was also imparted at ICRISAT Center, Patancheru for the farmers of Andhra Pradesh, Maharashtra and Uttar Pradesh. Details of these activities can be found in special project reports.

RK Srivastava and KB Saxena

Output target 2009 6.3.6 CAP NARS scientists' field days in sorghum, pigeonpea, groundnut, and chickpea organized

Achievement of Output Target:
100%
NARS scientists' field days were organized as proposed

Participating Countries:
India, Myanmar, Nepal, Ethiopia, Kenya, Tanzania, Australia, Philippines

Participating Partners:
NARS in above countries

Special Project Funding:
ICAR-ICRISAT Collaborative Projects, Tropical Legumes II, COGGO, ISOPOM, NSFM, IFAD, and OPEC Fund

Progress/Results:
Chickpea: Chickpea Scientists' Meet was organized during 8-9 Jan 2009 at ICRISAT-Patancheru. Over 40 scientists from 7 countries (Australia, Ethiopia, India, Kenya, Myanmar, Philippines and Tanzania) participated. There were two presentations – one each from ICRISAT and IIPR to provide an update on recent developments in chickpea research. A separate session was organized on ICAR-ICRISAT projects. The scientists visited different experiments and selected germplasm/breeding materials of their interests.

PM Gaur, CLL Gowda and Shailesh Tripathi

Groundnut
Groundnut scientists' meet was held at ICRISAT on 24 April 2009. Eighty scientists working on groundnut research from different parts of India visited groundnut fields and selected breeding populations and advanced breeding lines for use in their breeding programs. Seeds of 294 advanced breeding lines, 34 segregating populations and one international trial were supplied to 12 collaborators.

SN Nigam

Output target 2009 Capacity 6.3.6 CAP Farmer-participatory varietal selection trials conducted on legumes to enhance adoption of improved cultivars

Achievement of Output Target:
100%

Participating Countries:
India, Myanmar, Nepal and Vietnam

Participating Partners:
ICAR, SAUs and NGOs in India; DAR in Myanmar, NARC and NGOs in Nepal and VAAS in Vietnam

Progress/Results:
Chickpea:
- In India, three FPVS trials with 3 desi (JG 11, JG 130 and JAKI 9218) and 3 kabuli (KAK 2, JGK 2 and Vihar) varieties were conducted in 3 selected villages of Prakasam district. About 300 farmers (280 male + 18 female) evaluated the cultivars at the podding stage and preferred all three cultivars (JG 11, JAKI 9218 and JG 130) in desi type and one cultivar (KAK 2) in kabuli type.
- In Myanmar, 5 mother and 18 baby trials on six improved breeding lines [Kabuli: ICCV 97306, ICCV 97314, ICCV 97316, Desi: Yezin 6 (ICCV 92944), Shwenilongyi, Sinshweni (ZCHL 98907)] and two check cultivars [(Yezin 3 (ICCV 2), Yezin 4 (ICCV 88202)] were conducted in three divisions (Mandalay, Magway and Sagaing) during 2008/09 crop season. Three varieties, Sinshweni, Shwenilonegyi and ICCV 97316, were preferred by the farmers.

PM Gaur, CLL Gowda, Shailesh Tripathi and GV Ranga Rao

Pigeonpea:
- During the year 2009, a total of 12 mother and 35 baby trials were conducted in India (Maharashtra, Andhra Pradesh, Uttar Pradesh) and Nepal (Nepalgunj). In these trials scientists along with farmers selected varieties of their preference. Farmers were appraised about the maturity duration, disease reaction and adaptability of the varieties for a given agroecological region, and its suitability in the prevailing cropping systems. Scientists used the feed back from the farmers to document various farmer preferred traits.

- In Myanmar, the FPVS program in three divisions (Mandalay, Magway and Sagaing) was organized with 6 mother trials and 36 baby trials on 4 varieties (ICPL 96061, Thahtaykan, Monywashwedinga, ICPB 2043) one hybrid (ICPH 2671) and a local check. ICPL 96061 and ICPB 2043 were the most preferred varieties by the farmers.

RK Srivastava and KB Saxena

Groundnut:
- Farmer-preferred varieties (FPVs) identified through FPVS trials in India, Nepal and Vietnam include ICGV 91114, ICGV 00350, ICGV 00351, ICGV 86015, ICGV 00308, ICGV 87846, and ICGV 02266 in India; ICGV 86300 and ICGV 90173 in Nepal; and L 23 and L 26 in Vietnam.
- In Myanmar, the FPVS trials (6 mother trials and 36 baby trial) were conducted in three divisions (Mandalay, Magway and Sagaing). The varieties in FPVS trials included Sinpadaytha 7, Sinpadaytha 8, Sinpadaytha 11, Nyaung Oo 1, YZG 03008, YZG 04014, and a local check (SP121). The farmers selected Sin 8, Sin 11, YZG 03008 and YZG 04014 and initiated seed multiplication (2 ha each) for further scaling up program in the coming seasons.

SN Nigam

Output target 2009 6.3.6 CAP Farmer-friendly literature on crop management and seed production technology published and distributed to NARS

Achievement of Output Target:
100%

Participating Countries:
India, Nepal and Vietnam

Participating Partners:
SAUs in India, NARC in Nepal and VAAS in Vietnam

Progress/Results:
Chickpea:
A leaflet on production technology of chickpea "Sanaga Saagulo melakuvalu" was published in Telugu in February, 2009. Chickpea seed production folder "Kadale Bijothpadaneya Tanthrikathe" was published in Kannada in January 2009. Chickpea seed production manual in English, Telugu and Kannada have been prepared and are being processed for printing. These are expected to be published during early 2010.

PM Gaur, S Tripathi, CLL Gowda, GV Ranga Rao,
HC Sharma, S Pande, and M Sharma

Pigeonpea:
A total of nine farmer friendly literature on quality seed production, processing, storage integrated crop management (ICM) technologies, and dal milling were produced in association with PDKV Akola, ANGRAU Hyderabad, Dept. of Agriculture Uttrakhand. Of these, three bulletins are in Marathi, two in Telugu and three in Hindi and one in English (to be translated shortly in Phillipino) for the Phippiness. Details of these publications can be obtained from special project reports.

RK Srivastava and KB Saxena

Groundnut:
Farmer-friendly literature on crop management and groundnut seed production manual in English and vernacular languages (Tamil, Telugu, Kannada, Gujarati, Nepali and Vietnamese) are published and made available to partners and other stakeholders.

SN Nigam

MTP Output Targets 2010-11 and Output Targets not listed in the MTP

Output 6.1: Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of selection tools and breeding methods made available to partners internationally

Groundnut

Output target 6.1.1 GN Each year 50-60 diverse trait-specific (resistance to rust, late leaf spot (LLS), and other emerging diseases and pests, short- and medium-duration, dual-purpose (food and fodder), oil types and confectionery types), high yielding breeding populations and advanced breeding lines developed

Activity 6.1.1.1 GN Evaluate and introgress new germplasm sources (cultivated and wild *Arachis* species) of variability for yield components, resistance to rust, LLS, and other emerging diseases, crop duration and food and fodder quality traits

Milestone 8-10 selected advanced breeding lines in each partner country evaluated for local adaptation and farmer-preferred traits in SAT Asia 2009

Achievement of Output Target:
100%

Participating Countries:
None

Participating Partners:
None

Progress/Results:
One hundred and five new crosses (30 for foliar diseases resistance, 30 for short-duration, 20 for medium-duration with high oil content and 25 for confectionery traits with high protein content) were completed in the 2008/09 postrainy and 2009 rainy seasons to generate populations for selection for high yield, diseases resistance, required crop-duration and confectionery traits in desirable agronomic backgrounds. New parents used in hybridization included: LCBG 15, LCBG 28, TS 32-1, ICGV # 07116, 06042, 07043, 05089, 06184, 06142, 07076, and 07063 for resistance to foliar diseases; ICGV # 00308, 06042, 07043, 07223, L23, ICGV –IS # 87003-1, 96894-2, 96894-1, ICGV # 07210, 07213, 07084, and 07079 for short-duration; ICR # 37, 39, ICGV # 06046, 05155, 04017, 06138, 06319, 07063, 05141, and 03128 for medium-duration with high oil content and ICGV # 06234, 06199, 06118, 07075, 06211, 04017, 05191, 00298, 03226, 08047, 08076, 00323, and 06236 for confectionery traits with high protein content. The new parents involved germplasm accessions, advanced breeding lines, released cultivars and interspecific derivatives.

(a) Resistance to Foliar Diseases
Breeding populations
As foliar diseases pressure in the postrainy season is low 128 F_2-F_9 bulk selections were sown in the 2008/09 postrainy season mainly for selection for agronomic traits. From these 137 bulk selections were made and 54 advanced generations selections were identified for inclusion in replicated yield trials. Promising selections came from [(ICGS 76 x (ICGV 87841 x ICG 11337) x (CS 46)], (ICGV 94118 x ICGV 02429), and (ICGV 01352 x ICG 1391) crosses. Similarly during the 2009 rainy season, 138 F_2-F_{10} bulks were sown for further evaluation. From these, 119 bulks and 62 single plants were selected. The most promising selections came from (ICGV 94118 x ICGV 02429) and (ICGX 000038 x ICG 7899) crosses.

Yield trials
2008 rainy season: Due to shortage of irrigation water and delayed onset of monsoon, no foliar diseases resistant breeding populations and trials were sown in the 2008 rainy season.

2008/09 postrainy season: One hundred and thirty advanced breeding lines including controls were evaluated in six replicated trials (Preliminary, Advanced and Elite trials for Spanish and Virginia types) for agronomic traits. The following were the main findings-

- In Elite (Spanish) Trial line ICGV 07120 (6.5±0.51 t ha^{-1}, 73% shelling outturn, 58 g HSW, 48% oil content, 24% protein content, and 6.0 t ha^{-1} haulm yield) produced significantly higher pod yield than the highest yielding control GPBD4 (4.5 t ha^{-1} pod yield, 76% shelling outturn, 34 g HSW, 54% oil content, 21% protein content).

- In Elite (Virginia) Trial line ICGV 06175 (5.5±0.35 t ha^{-1}, 65% shelling outturn, 61 g HSW, 53% oil content, 24% protein content, and 7.5 t ha^{-1} haulm yield) produced significantly higher pod yield than the highest yielding control ICGV 98373 (4.4 t ha^{-1} pod yield, 62% shelling outturn, 54 g HSW, 49% oil content, 23% protein content).

- In Preliminary (Virginia) Trial five varieties (6.5-5.3±0.26 t ha^{-1} pod yield) produced significantly higher pod yield than the highest yielding control ICGV 98373 (4.2 t ha^{-1} pod yield, 60% shelling outturn, 58 g HSW). ICGV 08315 gave the highest pod yield (6.5 t ha^{-1} pod yield, 70% shelling outturn, 56 g HSW) followed by ICGV 08313 (6.4 t ha^{-1} pod yield, 65% shelling outturn, 46 g HSW).

2009 rainy season: One hundred and thirty one advanced breeding lines including controls were evaluated in six replicated trials. These trial data are being analyzed.

(b) Short-duration

Breeding populations
In 137 bulk populations and 108 single plant progenies grown in the 2008/09 postrainy season, 158 F_2-F_{11} bulks and 112 single plant selections, based on agronomic traits, were made. Of these, 21 bulk selections in advanced generations were identified for inclusion in replicated yield trials. In 158 bulk populations and 112 single plant progenies grown in the 2009 rainy season, 187 F_2-F_{12} bulks and 344

single plant selections, based on agronomic traits, were made. The most promising selections came from (ICGV 98294 x ICG 3540) and (ICGV 98294 X ICGV 99258) crosses.

Yield trials

Forty-one advanced breeding lines (including controls) in two replicated trials (Preliminary and Advanced trials) were evaluated in the 2008 rainy and 2008/09 postrainy seasons. The main findings are as below-

2008 rainy season: In Preliminary Trial at 90 DAS (1470 $^{\circ}$Cd) harvest, three varieties received from Vietnam outperformed (3.9-3.6±0.24 t ha^{-1} pod yield) the highest yielding early-maturing control TAG 24 (2.7 t ha^{-1} pod yield, 67% shelling outturn, 32 g HSW, and 52% oil content). EC 582664-1 ranked first in the trial (3.9 t ha^{-1} pod yield, 54% shelling outturn and 37 g HSW, and 50% oil content) followed by L 24 (3.8 t ha^{-1} pod yield, 56% shelling outturn and 47 g HSW, and 51% oil content).

2008/09 postrainy season: Out of 41 test entries no single test line significantly out performed the best yielding control variety. However in Preliminary Trial at 90 DAS (1470 $^{\circ}$Cd) harvest, ICGV-IS 96894-2 (4.6 t ha^{-1} pod yield, 60% shelling outturn and 39 g HSW, and 53% oil content) showed 10% yield advantage over best yielding control cultivar TAG 24 (4.0 t ha^{-1} pod yield, 70% shelling outturn and 44 g HSW, and 50% oil content).

*2009 rainy season***:** Thirty nine advanced breeding lines (including controls) were evaluated in two replicated trials in 2009 rainy season. The trial data are being analyzed.

(c) Medium-duration

Breeding populations

In the 2008/09 postrainy season, 160 bulk populations and 76 plant progenies were sown for evaluation. From these, 196 F_2-F_{11} bulks and 145 single plant selections were made. Of these, 34 bulk selections in advanced generations were identified for inclusion in replicated yield trials The most promising selections came from (ICGV 00037 x ICGV 00038) and (ICGV 99159 x ICGV 95047) crosses. Similarly in the 2009 rainy season, 152 bulk populations and 145 plant progenies were sown for evaluation. From these, 167 F_2-F_{12} bulks and 53 single plant selections were made. The most promising selections came from (ICGV 98103 x ICGV 95042), (ICGV 99159 x ICGV 95042), (ICGV 99159 x ICGV 95047), and (ICGV 02446 x ICGV 95469) crosses.

Yield trials

One hundred and sixty eight advanced breeding lines including controls were evaluated for yield in six replicated trials (Preliminary, Advanced and Elite trials for Spanish and Virginia groups) in the 2008 rainy and 2008/09 postrainy seasons. The salient findings in the two seasons are given below-

2008 rainy season
- In Elite Trial (Spanish), 42 out of 45 (5.7-3.1±0.31 t ha^{-1} pod yield) test varieties significantly out-yielded the highest yielding control JL 24 (2.1 t ha^{-1} pod yield, 67% shelling outturn, 33 g HSW, 50% oil content, 0.7 t ha^{-1} oil yield, and 20% protein content). In this trial eleven varieties gave more than 5 t ha^{-1} pod yield. ICGV 06042 ranked first (5.7 t ha^{-1} pod yield, 70% shelling outturn, 51 g HSW, 56% oil content, 2.23 t ha^{-1} oil yield, and 24% protein content) followed by ICGV 06051 (5.6 t ha^{-1} pod yield, 70% shelling outturn, 45 g HSW, 55% oil content, 2.16 t ha^{-1} oil yield, and 23% protein content).
- In Elite Trial (Virginia), only one test variety, ICGV 07043, produced significantly higher pod yield (5.2±0.30 t ha^{-1} pod yield, 62% shelling outturn, 35 g HSW, 54% oil content, 1.74 t ha^{-1} oil yield, and 23% protein content) than the highest yielding control ICGV 97115 (3.6 t ha^{-1} pod yield, 65% shelling outturn, 41 g HSW, 52% oil content, 1.22 t ha^{-1} oil yield, and 21% protein content).

- In advanced Trial (Spanish), ten (4.9-4.2±0.49 t ha^{-1} pod yield) test varieties significantly out-performed the highest yielding control ICGS 44 (3.2 t ha^{-1} pod yield, 64% shelling outturn, 51 g HSW, and 53% oil content, and 1.09 t ha^{-1} oil yield). ICGV 07063 ranked first in pod yield (4.9 t ha^{-1} pod yield, 60% shelling outturn, 52 g HSW, and 53% oil content, and 1.56 t ha^{-1} oil yield) followed by ICGV 07062 (4.9 t ha^{-1} pod yield, 65% shelling outturn, 45 g HSW, and 53% oil content, and 1.69 t ha^{-1} oil yield).

- In Preliminary Trial (Spanish), 32 out of 39 (5.1-3.4±0.41 t ha^{-1} pod yield) test varieties significantly outperformed the highest yielding control GPBD 4 (2.6 t ha^{-1} pod yield, 60% shelling outturn, and 31 g HSW). ICGV 08234 ranked first in pod yield (5.1 t ha^{-1} pod yield, 70% shelling outturn, and 46 g HSW) followed by ICGV 08228 (4.8 t ha^{-1} pod yield, 58% shelling outturn, and 50 g HSW).

- In Preliminary Trial (Virginia), three varieties produced significantly higher pod yield (3.7-3.1±0.41 t ha^{-1}) than the highest yielding control ICGS 76 (2.4 t ha^{-1} pod yield, 71% shelling outturn, and 41 g HSW). ICGV 08264 ranked first in pod yield (3.7 t ha^{-1} pod yield, 54% shelling outturn, and 22 g HSW) followed by ICGV 08272 (3.6 t ha^{-1} pod yield, 57% shelling outturn, and 41 g HSW).

2008/09 postrainy season
- In Advanced Trial (Spanish), ten (7.5-7.1±0.39 t ha^{-1} pod yield) test varieties significantly outperformed the highest yielding control ICGV 95070 (5.8 t ha^{-1} pod yield, 68% shelling outturn, 48 g HSW, and 55% oil content). ICGV 07063 ranked first in pod yield (7.5 t ha^{-1} pod yield, 67% shelling outturn, 58 g HSW, and 55% oil content) followed by ICGV 07147 (7.4 t ha^{-1} pod yield, 69% shelling outturn, 58 g HSW, and 56% oil content).

(d) High/low oil content

A set of 150 advanced breeding lines and 10 checks belonging to either high oil ($\geq$55% oil) or low oil ($\leq$45% oil) category were chosen from various sources. This set was evaluated for high/low oil in replicated trials during 2008 rainy and 2008/09 postrainy seasons. The salient findings during the two seasons are given below-

2008 rainy season: In this season 18 lines recorded high oil (58% - 55%) content and for pod yield 34 out of 150 (5.8-4.5±0.39 t ha^{-1} pod yield) test entries significantly outperformed the highest yielding control ICGV 00350 (3.4 t ha^{-1} pod yield, 66% shelling outturn, 29 g HSW,

and 53% oil content). ICGV 07229 ranked first in oil yield (2.24 t ha^{-1} oil yield, 5.8 t ha^{-1} pod yield and 55% oil content) followed by ICGV 06041 (2.00 t ha^{-1} oil yield, 5.5 t ha^{-1} pod yield, and 54% oil content) while the best check (ICGV 00350) gave 1.19 t ha^{-1}. ICGV 07026 and ICGV 99083 recorded the lowest oil yields ($\leq$ 159 kg ha^{-1}) surpassing the lowest oil yield check ICGV 91114 (592 kg ha^{-1} oil yield)

2008/09 postrainy season: In this season, 74 lines recorded high oil (60% - 55%) content and for pod yield 9 out of 150 (7.2-6.2±0.45 t ha^{-1} pod yield) test entries significantly outperformed the highest oil yielding control ICGV 00350 (1.7 t ha^{-1} oil yield, 4.8 t ha^{-1} pod yield and 57% oil content). ICGV 02411 and ICGV 07014 were the two best oil yielding lines (~2.7 t ha^{-1} oil yield and >55% oil yield). For low oil content the two best lines were ICGV07191 and ICGV 03094 (oil yield <817 kg ha^{-1} and oil content <50%) while the best check was TMV 2 (756 kg ha^{-1} oil yield and 50% oil content)

(e) High/low protein content

Similarly a set comprising of 52 advanced breeding lines and 8 checks for either high ($\geq$25% protein) or low ($\leq$18% protein) protein content was evaluated for high/low protein content in replicated trials during 2008 rainy and 2008/09 postrainy seasons. The salient findings in the two seasons are given below-

2008 rainy season: Eight lines recorded high protein (27% - 25%) content and significantly outperformed the best check (ICGV 86564, 21% protein content); ICGV 00323 and ICGV 04149 were the highest protein content lines (26-27%). The two lowest protein content lines (ICGV 97045 and ICGV 06359, ~17%) were on par with the corresponding check (TAG 24).

2008/09 postrainy season: Significant G x E for protein content was observed over seasons. In the post rain season 8 lines recorded high protein (27% - 25%) content and significantly outperformed the best check TAG 24 (23% protein content). Highest protein content of ~27% was recorded in lines ICGV 05195 and ICGV 02038 while the best check TAG 24 yielded 23% protein. ICGS 76 was the check with lowest protein content (16%) while among lines the lowest recorded protein content was 18%.

2009 rainy season: Ninety eight for medium-duration and three hundred and seventeen four high/low oil and high/low protein advanced breeding lines including controls in ten replicated trials were evaluated. These trial data are being analyzed.

(f) Confectionery traits

Breeding populations: During the 2008/09 postrainy season, 137 selections were planted for evaluation. From these, 97 F$_2$-F12 bulks and 207 single plants were selected. Of these, 37 in advanced generations were identified for inclusion in replicated yield trials. The most promising selections came from (ICGX 950067 x ICGX 950069), (ICGX 960238 x ICGV 02250) and (ICGV 01393 x ICGV 86564) crosses. Similarly in the 2009 rainy season, 279 selections were planted for evaluation. From these, 195 F$_2$-F$_9$ bulks and 209 single plants were selected. The most promising selections came from (ICGV 00440 x ICGX 960065), (ICGV 99159 x ICGV 00451), and (ICGV 94215 x ICGV 86564) crosses.

Yield trials: One hundred and twenty five advanced breeding lines including controls were evaluated in replicated trials in the 2008 rainy and 2008/09 postrainy seasons. The main findings are given below-
2008 rainy season:

- In Elite Trial (Spanish), two varieties, ICGV 06199 (4.2±0.22 t ha^{-1} pod yield, 56% shelling outturn, 45 g HSW, 43% oil content, 24% protein content, and 1.41 O/L ratio) and ICGV 06189 (3.7 t ha^{-1} pod yield, 67% shelling outturn, 57 g HSW, 48% oil content, 21% protein content, and 1.70 O/L ratio), produced significantly higher pod yield than the highest yielding control ICGV 99085 (2.3 t ha^{-1} pod yield, 65% shelling outturn, 53 g HSW, 48% oil content, 18% protein content, and 1.59 O/L ratio).

- In Elite Trial (Virginia), two varieties, ICGV 06234 (4.2±0.18 t ha^{-1} pod yield, 65% shelling outturn, 60 g HSW, 51% oil content, 21% protein content, and 1.56 O/L ratio) and ICGV 06216 (3.2 t ha^{-1} pod yield, 61% shelling outturn, 51 g HSW, 40% oil content, 23% protein content, and 1.47 O/L ratio), produced significantly higher pod yield than the highest yielding control ICGV 00440 (2.8 t ha^{-1} pod yield, 63% shelling outturn, 57 g HSW, 43% oil content, 21% protein content, and 1.70 O/L ratio).

- In Preliminary Trial (Spanish), only one test variety ICGV 08052 (4.1±0.27 t ha^{-1} pod yield, 62% shelling outturn, 48 g HSW) produced significantly higher pod yield than the highest yielding control ICGV 97045 (2.0 t ha^{-1} pod yield, 58% shelling outturn, and 47 g HSW).

- In Preliminary Trial - 1 (Virginia), ICGV 08086 test entry (4.1±0.20 t ha^{-1} pod yield, 57% shelling outturn, 53 g HSW) produced significantly higher pod yield than the highest yielding control ICGV 00440 (2.9 t ha^{-1} pod yield, 63% shelling outturn, and 56 g HSW).

- In Preliminary Trial - 2 (Virginia), only one test variety ICGV 08134 (3.6±0.25 t ha^{-1} pod yield, 62% shelling outturn, 60 g HSW) produced significantly higher pod yield than the highest yielding control ICGV 00440 (2.7 t ha^{-1} pod yield, 61% shelling outturn, and 44 g HSW).

2008/09 postrainy season:

- In Elite Trial (Spanish), ICGV 06188 (6.0±0.25 t ha^{-1} pod yield, 68% shelling outturn, 78 g HSW, 45% oil content, and 27% protein content) produced significantly higher pod yield than the highest yielding control ICGV 99085 (5.1 t ha^{-1} pod yield, 68% shelling outturn, 81 g HSW, 52% oil content, and 19% protein content).

- In Preliminary Trial - 2 (Virginia), only one test variety ICGV 08110 (5.7±0.29 t ha^{-1} pod yield, 71% shelling outturn, and 91 g HSW) produced significantly higher pod yield than the highest yielding control Somnath (4.8 t ha^{-1} pod yield, 67% shelling outturn, and 43 g HSW).

2009 rainy season: Sixty one advanced breeding lines including controls were evaluated in four replicated trials. The trial data are being analyzed.

SN Nigam

Milestone Farmer-preferred variety(ies) in each partner country identified 2010

Achievement of Output Target:
100%

Participating Countries:
India, Nepal and Vietnam

Participating Partners:
ICAR and SAUs in India; NARC in Nepal, and VAAS in Vietnam

Progress/Results:
The farmer-preferred varieties in different legume crops (India- groundnut, chickpea, pigeonpea and blackgram; Nepal- groundnut, chickpea, pigeonpea, phaseolus bean, soybean, blackgram, greengram and lentil and Vietnam- groundnut and soybean) have been identified in partner countries. These include the following:

India
Groundnut: ICGV 91114 in AP, Orissa and Jharkhand and ICGS 76 in Chhattisgarh
Chickpea: ICCC 37, JG 11, KAK 2 and JGK 2 in Chhattisgarh, ICCC 37 and KAK 2 in Jharkhand
Pigeonpea: ICP 8863 and ICPL 85063 in Chhattisgrah, ICP 7035 (Kamica), ICPL 88039 and ICPH 2671 in   Jharkhand, ICPL 87119 (Asha), ICP 7035 and ICPL 87051 in Orissa
Blackgram: Ujala in Orissa

Nepal
Groundnut: Rajarshi and Baidehi
Chickpea: Avarodhi and Tara
Pigeonpea: Rampur Rahar 1, ICP 7035, ICPL 86005, Pusa 9 and Pusa 14
Phaseolus bean: PB 0001, PB 0002 and PB 0048
Soybean: Puja and Tarkari Bhtamas 1
Greengram: Kalyan and Pratkcha
Lentil: ILL 7723 and Shital

Vietnam
Groundnut: L 14 and L 23; Soybean: DT 12 and DT 22; Mungbean: DX 11

Special Project Funding:
IFAD and ISOPOM

<div align="right">SN Nigam</div>

Milestone Five interspecific derivatives of groundnut evaluated for TSV and peanut bud necrosis virus (PBNV) diseases and promising lines identified 2010

Achievement of Output Target:
60%
The interspecific derivatives were evaluated earlier for resistance to TSV and PBNV. Some promising derivatives were identified which will be evaluated during 2010

Participating Countries:
None

Participating Partners:
None

Progress/Results:
No activity during 2009

Special Project Funding:
None

<div align="right">Nalini Mallikarjuna</div>

Output target 2011 6.1.1 GN Five stable interspecific derivatives of groundnut with resistance to LLS tested on farmers' fields

Achievement of Output Target
60%
Interspecific derivatives with resistance to LLS have been identified and will be evaluated again during 2010
Participating Countries:
India

Participating Partners:
UAS-Dharwad and UAS-Raichur

Progress/Results:
Advance generation interspecific derivatives which showed resistance to LLS on ICRISAT's experimental fields were tested for LLS disease reaction at UAS-Dharwad and UAS-Raichur. Many of the lines which showed a disease score of 4 at ICRISAT showed a disease score of 4 at UAS-Dharwad too. Results from UAS-Raichur are awaited.

Special Project Funding:
None

Nalini Mallikarjuna and Kenchengoudar (UAS-Dharwad)

Activity 6.1.1.2 GN Develop a better understanding of inheritance of components of resistance to late leaf spot (LLS) and confectionery traits

Milestone Knowledge of inheritance of confectionery traits in two crosses gained and appropriate breeding strategy devised 2010

Achievement of Output Target:
75%
The required experiments have been completed. A manuscript describing the experiment, results and proposed breeding strategy is to be completed in 2010.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Six generation inheritance data is available in two crosses – ICGV 01393 x Chico and ICGV 02251 x Chico; generation mean analysis is in progress to elucidate inheritance pattern of confectionery traits.

Special Project Funding:
ISOPOM, TL II and The OPEC Fund

SN Nigam

Output target 2011 6.1.2 GN Three mapping populations for LLS and two for confectionary traits developed

Achievement of Output Target:
70%
The mapping populations are in F_8 and F_6 generations. They will be advanced to next generations during 2010.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
During the 2009 rainy season, 561 F_8 RILs of JL 24 x ICG 11337 cross and 861 F_8 RILs of JL 24 x ICG 13919 cross were advanced to develop mapping populations. One cross (ICG 11337 x ICG 13919) was discontinued as it was resistant x resistant type. For confectionary trait 678 and 781 F_6 RILs in ICGV 01393 x Chico and ICGV 02251 x Chico crosses respectively were advanced to develop mapping populations.

Special Project Funding:
ISOPOM, TL II and The OPEC Fund

SN Nigam

Output target 2010 6.1.2 GN Promising transgenic events of groundnut for resistance to TSV and PBNV available for commercialization and introgression in locally adapted germplasm

Activity 6.1.2.1 GN Develop transgenic events of groundnut for resistance to TSV and evaluate their performance under contained greenhouse and field conditions

Output target 2010 6.1.2 GN Two transgenic events with resistance to TSV used for introgression into locally adapted groundnut genotypes

Achievement of Output Target:
50%
The transgenic events have been screened under contained greenhouse conditions and the promising events have been identified and needs further evaluation using the vector mediated virus transmission. Efforts are underway for comprehensive evaluation of the selected events which will be then phenotyped in strip trial under field conditions in 2010.
Participating Countries:
None

Participating Partners:
None

Progress/Results:
The transgenic events (18; including the ones showing delayed symptoms) that showed promise in virus challenging assays are being advanced to subsequent generations (T3) in the containment greenhouse for seed multiplication and to study the inheritance pattern and further evaluations. The selected transgenic groundnut events were confirmed by PCR and RT-PCR before subjecting for virus challenging.

Standardization of virus challenging is important before subjecting them for strip trials and subsequent introgression into locally adapted groundnut genotypes; hence virus challenging experiments were carried out using both sap inoculation as well as vector (thrips) mediated procedures. These methods were standardized for obtaining consistent results under greenhouse conditions. This was done by standardizing the optimum dilution of *tobacco streak virus* using the untransformed control plants before carrying out the phenotypic evaluation of groundnut transgenic events. These experiments were carried out with modifying various conditions such as the extraction buffer, utilizing anti oxidants such as Thioglycerol and Sodium sulfite, abrasives dusting carborundum alone, mixing celite and carborundum in the inoculum and mixing celite and carborundum in the inoculum followed by dusting carborundum on leaves at various inoculum dilutions of 1:60, 1:120, 1:240, 1:300, using virus source from French bean cv. Top Crop and cowpea cv.C-152. These conditions were tried to determine the optimum conditions and dilution for obtaining 100% mechanical transmission of TSV on groundnut variety JL-24. These studies resulted in optimization of conditions for inoculum preparation by using sodium sulfite as an anti oxidant, mixing celite and carborundum in the inoculum followed by dusting carborundum on leaves at a dilution of 1:240 which ensured 100% infection on JL-24. Delay in symptom expression was not observed at higher dilutions.

Phenotypic evaluation of the transgenic plants was also carried out using thrip mediated transmission of virus. Since, vector-mediated virus challenging is expected to reduce the chance of varying viral loads in the inoculum which is an important factor in standardization of virus challenging experiment. Field grown parthenium plants infected with TSV were identified using ELISA. Pollen was collected from these plants for use as TSV source. The transgenic plants were grown in small pots and were kept under cellulose butyrate cage having ventilators of 40 mesh. Eight day old test plants were sprinkled with TSV infected parthenium pollen and 10 thrips/plant were released in these cages. Thrips were allowed to feed for 48 hours after which dimethoate @ 2 ml/L was sprayed to kill thrips. Plants were observed for symptom development for 15 days. Both the symptomatic as well as symptomless plants were tested by ELISA for the presence of virus. The selected plants which did not show any symptoms of the disease were allowed to complete their life cycle and seeds were harvested for further evaluations.

Additionally, over 50 marker free transgenic events carrying the TSV cp gene have been developed and have been characterized at molecular level using routine procedures. Besides, the TSV cp expression and purification studies in bacterial system, pepsin digestibility with the crude recombinant protein i.e. TSV coat protein was carried out and found that it is digested completely within a minute in the SGF (simulated grastric fluid) and it is confirmed by subjecting the digested protein samples to SDS-PAGE and western blot. Biosafety data pertaining to protein heat stability, and pepsin digestibility assays as prerequisites for conducting contained field evaluations of these transgenic events. Although RCGM permitted us to carry out the confined field strip trials for event selection during the rainy season of 2009, this trial could not be conducted due to unfavorable kharif season due to lack of rains.

Special Project Funding:
None

KK Sharma, Pooja Bhatnagar-Mathur and SN Nigam

Activity 6.1.2.2 GN Develop transgenic events of groundnut for resistance to PBNV and evaluate their performance under contained greenhouse and field conditions

Output Target 2011 6.1.1 GN At least 10 transgenic events with resistance to PBNV characterized under greenhouse conditions

Achievement of Output Target:
75 %
The transgenic events have been developed using the antisense RNA for *PBNVnp* gene and are currently undergoing evaluation under contained greenhouse conditions. We expect to meet the target set for 2011.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Virus challenging of 48 transgenic groundnut events that were previously developed for resistance to PBNV using the nucleocapsid protein (*PBNVnp*) gene indicated that only 4 events showed lower disease incidence compared to the control JL 24. The T_2 progenies from virus challenged (promising transgenic events) events were selected through molecular and phenotypic characterization and have been progressed to T6 generation. The lower frequency of virus resistant events concluded that apparent lack of resistance to PBNV in transgenic plants could be attributable to the presence of RNA silencing suppressor gene (NSs) in the PBNV genome, which could be rendering *PBNVnp* gene ineffective. Therefore, an alternate strategy based on RNA interference (antisense and hairpin-RNA) mediated gene silencing has been initiated.

The PBNVnp gene in an antisense orientation driven by the double 35S CaMV promoter was cloned in a marker-free plasmid (pZPP200) and mobilized into *Agrobacterium tumefaciens* strain C58 for the transformation of tobacco as a model system and groundnut. Among 52 T_0 events, 22 have been screened positive based on PCR, RT-PCR and western analysis and have been progressed to T_1 generation for multiplication. Besides, a variant of above construct that harbors genes encoding schaffold attached region protein (SARp) flanking the PBNV insert in the pPZP200 have also been developed. Among 12 T_0 putative transformants 11 have shown positive PCR and RT-PCR results. These have been progressed to T_1 generation for segregation analysis and further screening. Currently five transgenic events are undergoing virus challenging under greenhouse conditions
Moreover, test virus challenge experiments for a set of T_5 transgenics inferred a requirement to optimize conditions and dilutions of inoculum and accordingly a glass house experiment was conducted by testing various requisites. From the experiment it was concluded that PBNV from groundnut as source of inoculum utilizes inoculation buffer (phosphate buffer) with supplements viz., sodium sulfite as an anti-oxidant, celite and carborundum followed by dusting carborundum on leaves at a dilution of 1:10 during winter period and 1:30 during other periods ensure 100% infection on JL-24. Delay in symptom expression was not observed at higher dilutions.

In order to establish the molecular mechanisms of regulation involved in, i) the expression levels of nucleocapsid protein (NP) gene of PBNV (sense and antisense orientations) in transgenic events, ii) enhancement or break of the introduced resistance to PBNV in hereby developed transgenic plants after virus challenging and iii) plant (transgenic) - virus interaction at molecular level during virus challenging

through Real-Time PCR was initiated. Simultaneously, strategies are being developed for *hairpin RNA* mediated gene silencing. Since the virulence factor and vital genes of PBNV are not known so far, many genes can be targeted and the silencing effects of individual gene can be studied. For example genes such as NP (nucleoprotein), NSm (movement protein) and NSs (Silencing suppressor protein) have been identified and gene specific primers were designed for amplification of desired gene fragments. The cloning work to construct the hairpin-RNA constructs has been initiated.

Special Project Funding:
None

Pooja Bhatnagar-Mathur, KK Sharma, and SN Nigam

Chickpea

Output target 6.1.1 CP 50-100 chickpea breeding lines with high yield, improved seed traits and resistance to one or more biotic stresses [Fusarium wilt (FW), Ascochyta blight (AB), Botrytis gray mold (BGM) and *Helicoverpa* pod borer] developed and disseminated to NARS

Activity 6.1.1.1 CP Develop chickpea breeding lines (desi and kabuli) with enhanced resistance to AB, BGM and FW

Milestone 15-20 desi and kabuli chickpea breeding lines with combined resistances to FW, AB and BGM developed 2010

Achievement of Output Target:
80%
Several breeding lines with resistance to FW, AB and BGM have been developed. These will be evaluated further during 2010

Participating countries:
Australia and India

Participating Partners:
Australia: University of Western Australia; CLIMA and Department of Agriculture and Food Western Australia (DAFWA); *India:* Punjab Agricultural University, Ludhiana

Special Project Funding:
Accelerated Genetic Improvement of Desi Chickpea, funded by Council of Grain Growers Organization Ltd. (COGGO), Western Australia.

Progress/Results:
Development of desi chickpea breeding lines with combined resistance to fusarium wilt (FW), ascochyta blight (AB) and botrytis gray mold (BGM): Total 58 new crosses were made during the crop season 2008/09 and during off-season in 2009 in the glasshouse (12 intercrosses for combining ABR and FWR with earliness, 16 crosses for combining ABR + FWR with earliness, 12 crosses incorporating salinity tolerance from ICC 7819 and CSG 8962, 12 for resistance to AB pathotype IV from ICC 12964 and ICC 18965, and 6 for pyramiding genes for resistance to FW, AB and BGM in Western Australia (WA) adapted breeding lines (WACPE 2152, 2162, 2113, 2114, 2125 and 2131)).

F_1s of 30 crosses, including 6 intercrosses were grown during the crop season 2008/09 (Oct 2008 – Feb 2009). These crosses aimed at developing early maturing breeding lines with combined resistance to ascochyta blight (AB), fusarium wilt (FW), botrytis grey mold (BGM) and salinity tolerant lines resistant to AB. Forty F_2 and 34 F_3 populations were harvested as early and medium bulks during 2008/09 crop season.

AB + BGM resistant progenies evaluated along with checks for phenology and yield in the normal field and for resistance to fusarium wilt in the wilt sick field: F_6-F_8 AB resistant single plant progenies (608) were evaluated for phenology, yield, resistance to fusarium wilt (at ICRISAT, Patancheru) and resistance to AB under field conditions (at PAU, Ludhiana). 181 lines recorded AB score less than that of Genesis 836 (AB score = 5) at seedling stage at ICRISAT. 195 lines showed resistance to AB (≤ 4 score) under field conditions at PAU (Genesis 836, Sonali and Rupali had AB score 5). Seventy-six lines showed good resistance to AB (≤ 4 score) both at seedling stage (at ICRISAT) and at adult plant stage (at PAU). Eighty-six lines showed 10 – 90% yield superiority over the best check for yield (Genesis with seed yield 1208 kg/ha). All the lines showed high wilt incidence (>50% mortality). Six lines had good combination of AB resistance (≤ 4 score both at ICRISAT and PAU), maturity < 110 days and seed yield higher than that of Genesis 836 (1208 kg/ha).

Over 1000 new progenies (479 F_4 + 632 F_5 to F_6) were grown and observations were recorded on phenology and plant type (based on visual score on a 1 – 5 scale, where 1 – best and 5 – poor). 544 plants had visual rating ≤ 3 and maturity ranging from 97 – 115 days.

Over 400 progenies selected from the lines earlier supplied to WA were evaluated along with WA checks for agronomic traits and yield. Fifty-three lines were found superior to Genesis 836 (best check for yield with seed yield 1818 kg/ha) out of which 47 had seed size better than that of WACPE 2078 (100-seed weight = 17.3 g).

Breeding lines (118) received from DAFWA were also evaluated for phenology, yield and AB resistance at ICRISAT. One set of these lines was evaluated at PAU, Ludhiana for AB resistance under field conditions. Twenty-three lines had high AB resistance (≤ 2 score) under field conditions at PAU. Fifty-one lines had AB resistance more than that of Genesis 836 (AB score = 5) at ICRISAT. Seventeen lines showed better resistance to AB (AB score ≤ 2 at PAU and ≤ 5 at ICRISAT) than the best resistant check (Rupali at PAU (AB score = 2) and Genesis 836 at ICRISAT (AB score = 5). Only 3 lines (line no. 108, 109 and 111) surpassed the best check Moti (2233 kg/ha) in terms of yield.

PM Gaur, Shailesh Tripathi, CLL Gowda, Suresh Pande and Mamta Sharma

Desi and Kabuli F_4 populations for resistance to wilt: In collaboration with breeders, 78 F_4 populations (44 Desi + 34 Kabuli) were evaluated for wilt resistance in wilt sick plot under artificial epiphytotic conditions following standard field evaluation technique at ICRISAT-Patancheru. Among the 44 desi populations, no line was found resistant to wilt. However, two lines (ICCX-060035-F4 and ICCX-060119-F4) were found moderately resistant (10.1 to 20% incidence) to wilt. Among the kabuli populations, all the lines were susceptible to wilt.

Combined resistance to FW and AB: In collaboration with Australia under the COGGO project, segregating and advanced generation (F6-F8) populations were evaluated in the wilt sick plot for FW resistance (628 lines). Out of 628 entries, one entry (ICCX-040062-F5-BP-P96-P1) found asymptomatic (0% incidence) and two entries (ICCX-040026-F4-BP-P13-P1 and ICCX 040129-F4-BP-P244-P2) found moderately resistant to FW. About 2359 resistant single plants were selected and transplanted.

Combined resistance to AB, BGM and wilt: A set of 167 desi breeding lines were evaluated for AB, BGM and wilt. Combined resistance was not found in any of the lines. However, four lines were moderately resistant to wilt, 44 moderately resistant to BGM and 47 asymptomatic and 16 resistant to wilt.

<div align="right">Suresh Pande, Mamta Sharma, PM Gaur, Shailesh Tripathi and CLL Gowda</div>

ICAR-ICRISAT collaborative research on wilt, AB and BGM resistance in chickpea: Under the All India Coordinated Research Project for chickpea (AICRP-CP), 422 trial entries (IVT –desi (26), AVT 1-large seeded (4), AVT 1-late sown (4), IVT-late sown (20), IVT-rainfed (21), AVT-kabuli (11), AVT-extra large kabuli (9), IVT-kabuli (10), IVT-extra large kabuli (5), National Nursery - NNW lines (136), Donor lines (11), National Nursery – NND lines (74), National Nursery – NNB lines (58), P lines (24) and K lines (9) were evaluated for FW resistance in wilt sick plot and for AB and BGM under controlled environmental conditions at ICRISAT, Patancheru.

FW resistance: Hundred per cent wilt incidence was recorded in early wilting cultivar, JG 62 within 30 DAS and in late wilting cultivar, K850 in 90 DAS. Among the IVT-desi, AVT 1 (large seeded) and AVT 1 (late sown) no entry was found resistant to wilt. Among the IVT-late sown, one entry (IPC 2005-29) was found resistant (0.1-10% incidence). Of the twenty one IVT- rainfed entries one entry (PG 03203) found moderately resistant to wilt. Among the AVT1- kabuli, AVT1- extra large seeded kabuli, IVT kabuli and IVT-extra large seeded kabuli no entry was found resistant to wilt. Among the 11 donor lines two entries (D25 and D26) were moderately resistant to wilt. Among the National Nursery entries, out of 136 NNW lines, three lines (JSC 37, JSC 40 and JSC 39) showed resistant reaction (0.1-10%) and seven entries showed moderately resistant reaction (10.1-20%) to wilt. Among the 74 NND lines no entry was found resistant. Out of 58 NNB lines, no entry was found resistant and one entry (CSJ 515) moderately resistant to wilt. Among the 24 P lines (confirmation of resistance against major disease) no entry was found resistant to wilt.

AB resistance: Among the IVT-desi, two entries (H04-67 and GJG 0619) were moderately resistant. Combined resistance to AB and wilt was found in H04-67. Among IVT-late sown, one entry (H04-49) had moderate resistance to AB. All the AVT 1 (late sown), AVT 1 (large seeded), AVT (kabuli), IVT (kabuli) and IVT (rainfed) entries were susceptible to AB. Of the AVT1- extra large seeded kabuli, one entry (Phule G 9933-10) had moderate resistance to both AB and wilt. Among IVT- extra large seeded kabuli, three entries (H04-180, IPC 2004-29 and JGK 5) were moderately resistant to AB. Four entries (IPC 2002-29, GL 23094, GG 1362, GL 24021) were confirmed to have resistance to AB.

BGM resistance: Among the IVT-desi, two entries (KGD 1255 and NDG 8-101) were resistant and one entry moderately resistant to BGM. Of the AVT 1 (late sown), two entries (BGM 562 and RSG 973) were moderately resistant; IPC 2006-12 was resistant among IVT (rainfed), GL21013 among AVT 1 (large seeded), GLK23008 showed combined resistance to BGM and wilt. Vihar and Phule G 9737 showed combined resistance to BGM and dry root rot. All the AVT 1 (extra large seeded kabuli) and IVT (extra large seeded kabuli) were moderately resistant to BGM. Among the national nursery for BGM, four entries were moderately resistant to BGM.

<div align="right">Suresh Pande, Mamta Sharma and AICRP Collaborators</div>

ICRISAT-UAS Dharwad collaborative research on wilt resistance in chickpea: Three hundred and fifty chickpea RILs received from UAS, Dharwad were evaluated for wilt resistance in wilt sick plot under artificial epiphytotic conditions. Segregation for wilt resistance among these RILs was observed, however, four RILs were found resistant (0.1-10% incidence) and seven moderately resistant (10.1-20.0% incidence) to wilt.

<div align="right">Suresh Pande, Mamta Sharma and RL Ravikumar</div>

Advanced wilt and root rot promising selections for resistance to wilt: A total of 56 further advanced wilt promising selections and 34 further advanced wilt and root rot promising selections from ICRISAT were evaluated for wilt and root rots resistance in multiple disease sick plot (MDSP) under artificial epiphytotic conditions following standardized screening technique. Of the 56 advanced wilt promising selection, 2 lines (ICCV 08116 and ICCV 08317) had resistant reaction showing <10% wilt incidence and 20 were moderately resistant (10.1-20% incidence) to wilt. Of the 34 further wilt and root rot promising lines, 3 lines (ICC 14433, ICC 16124 and BCP 201) had shown resistant reaction (<10% wilt) and 15 were moderately resistant (10.1-20% incidence) to wilt.

<div align="right">Suresh Pande and Mamta Sharma</div>

Activity 6.1.1.2 Develop chickpea breeding lines with resistance to *Helicoverpa*

Milestone 5-10 sources of resistance and advanced lines tested for stability of resistance across locations (in India, Myanmar & Ethiopia) 2009

Achievement of Output Target:
60%
Germplasm lines with pod borer resistance have been identified, while breeding for pod borer resistance and high grain yield is a continuing process.

Participating Countries:
India

Participating Partners:
Indian Institute of Pulses Research

Special Project Funding:
Tropical Legumes Project II - Gates Foundation, ISOPOM project on Helicoverpa resistance- ICAR

Progress/Results:
Evaluation of germplasm and breeding lines for resistance to pod borer, *Helicoverpa armigera*. We evaluated a set of 95 germplasm and breeding lines earlier selected to be less susceptible to pod borer, *H. armigera*, in a RCBD with two replications. Data were recorded on

H. armigera damage at the vegetative and maturity stages, disease incidence, and grain yield. The genotypes ICC 4856, ICC 5264-E10, ICC 6122, ICC 9966, ICC 10236, ICC 10807, ICC 11340, ICC 11574, ICCL 79048, ICCL 86105, ICCX 730025-11-3-1H, ICCX 730103-12-2-1P{-LB-B1, ICCX 730179-9-4-1H, ICCX 730185-2-4-1H, ICCX 730304-14-2-1H-B-B, K 850, and Annigeri suffered moderate levels of damage by the pod borer (DR <4.0 compared to 8.4 in ICC 3137), and also exhibited low disease susceptibility (score<3.5 compared to 8.5 in ICC 506), and high grain yield potential (>10 q ha^{-1}). These lines will be screened further to identify lines with multiple insect and disease resistance.

<div align="right">HC Sharma and CLL Gowda</div>

Evaluation of advanced breeding lines for resistance to *Helicoverpa armigera*: We evaluated 44 advanced chickpea lines developed for resistance to pod borer, *H. armigera* along with six resistant and susceptible checks in a RCBD under natural infestation in the field. Data were recorded on *H. armigera* damage at the vegetative and maturity stages visually on a damage rating (DR) scale of 1 to 9 (1 = <10% leaf area/pods damaged, good pod setting, and pods uniformly distributed all over the plant, and 9 = >80% leaf area/pods damaged, poor pod setting, and pods present on a few branches only), pod damage (%), and disease resistance (1 = highly resistant, and 9 = highly susceptible), and grain yield. Damage rating scores for *H. armigera* ranged from 1.5 to 6.5, and 2.0 to 8.5 at the vegetative and maturity stages, respectively. The genotypes ICCX 960183-8, ICCX 960183- 20, ICCX 960183 – 69, C 9805 x BP-BP-BP-8, C 9802 x BP-BP-BP-43, ICCX 960183-28, and C 9905 x BGH-BP-BP-32 suffered lower pod borer damage at the vegetative and maturity stages, and also exhibited lower disease susceptibility (*Fusarium* wilt and dry root rot) than ICC 3137 (DR 6.5 and 8.5 at the vegetative and maturity stages, and disease score of 7.0). These lines also exhibited <12% pod damage compared to 34.78% in ICC 3137, and showed a yield potential >20 quintals ha^{-1} compared to 5.9 of ICC 3137 and 17.5 of ICCV 10.

<div align="right">HC Sharma and CLL Gowda</div>

Evaluation of advanced kabuli/desi breeding lines for resistance to *Helicoverpa*: We evaluated the Kabuli international chickpea nursery (20 genotypes) for resistance to the pod borer, *H. armigera* under natural infestation in the field. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative and maturity stages visually on a damage rating (DR) scale of 1 to 9 (1 = <10% leaf area/pods damaged, good pod setting, and pods uniformly distributed all over the plant, and 9 = >80% leaf area/pods damaged, poor pod setting, and pods present on a few branches only), overall resistance score (1 = highly resistant, and 9 = highly susceptible), pod damage (%), wilt (%), and grain yield. Damage by *H. armigera* larvae at the vegetative stage ranged from 2.5 to 5.5 (moderate damage), and at maturity 4.0 to 7.5, and the genotypes ICCV 07304, ICCV 07311, and ICCV 07312 suffered lower pod borer damage (DR <4.0) than ICCV 0730101 (DR 7.5). These lines were also less susceptible to diseases.

In another trial, we evaluated the Desi international chickpea nursery (20 genotypes) for resistance to the pod borer, *H. armigera* under natural infestation. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage as described above. Damage by *H. armigera* larvae at the vegetative stage ranged from 2.5 to 4.5, and at maturity from 1.5 to 6.5. The genotypes ICCV 07101, ICCV 07102, ICCV 07106, ICCV07113, and ICCV 07118 suffered lower pod borer damage and also exhibited less susceptibility to diseases, and showed a yield potential of >20 q ha^{-1} as compared to 17.18 q ha^{-1} of ICCC 37.

International chickpea *Helicoverpa* resistance screening nursery: This trial comprised of genotypes showing resistance to Helicoverpa armigera in the reference collection (10 lines), interspecific mapping population (5 lines), promising entries from the breeding material (5 lines), and five resistant and susceptible checks were sown about 2 weeks later than the normal sowing time or the sowing time so that the test material is exposed to optimum levels of H. armigera. Each entry was planted in a 2-row plot, 2 m long. There are three replications in a randomized complete block design. Observations were recorded on plant stand 2 weeks after seedling emergence, days to 50% flowering, and days to maturity. Numbers of H. armigera were recorded at the flowering stage, while the pod damage and overall damage rating (1 = highly resistant, and 9 = highly susceptible) were recorded at maturity. The leaf feeding at the vegetative stage was rated visually on a 1 to 9 scale, where: 1 = < l0% of the leaf area damaged, and 9 = >80% leaf area damaged.

At the dough stage of pod development, the trial was evaluated for H. armigera damage in the pods visually on a 1 to 9 damage rating scale (1 = <10% pods damaged, and 9 = >80% pods damaged). Data were also recorded on time to 50% flowering and maturity to compare the relative susceptibility of different genotypes. At crop harvest, count the total number of pods and the pods with pod borer damage in 10 plants selected at random in the center of each plot were also recorded. Grain yield was also recorded in each plot at crop harvest. Additional information on susceptibility to diseases was also recorded.

At ICRISAT - Patancheru, the genotypes ICC 4958, ICC 14402, ICC 14831, ICCV 07113, ICCV 07106, ICCV 07105, and ICCV 10 suffered low leaf damage during the vegetative and poding stages, and/or had low numbers of *H. armigera* eggs and larvae. The genotypes ICC 14402, ICC 14831, ICCV 07113, ICCV 07106, ICCV 07104, and ICCV 07105 yielded >1.5 t ha^{-1} as compared to 1.0 t ha^{-1} of ICC 3137.

<div align="right">HC Sharma, CLL Gowda and AICCIP Entomologists</div>

Output target 2011 6.1.1 CP Breeding lines (10) with combined resistance to Fusarium wilt and Helicoverpa identified

Achievement of Output Target:
75%
Twelve lines with resistance to fisarium wilt and moderate levels of resistance to pod borer identified. These will be evaluated further during 2010.

Participating Countries:
India, Myanmar, Nepal, Ethiopia, Tanzania and Kenya

Participating Partners:
IIPR, Kanpur; DAR-Yezin; EIAR, Addis Ababa; KARI, Nairobi; NZARDI, Arusha

Progress/Results:
- Sixty one fresh crosses were made to incorporate resistance to FW and Helicoverpa to adapted high yielding varieties. This included 25 single crosses, 11 three-way, and 25 four-way crosses.
- We screened 96 F$_3$ populations (71 from diallel and 25 other crosses) for resistance to FW and Helicoverpa. From these, we made 2860 single plant selections for progeny evaluation in next season.

- From 28 progenies evaluated in Advanced Yield Trial, we selected 15 promising lines showing low pod borer damage & high yield. Out of 44 progenies evaluated in Preliminary Yield Trial, we selected 24 promising lines based on low pod borer damage and high yield.
- **Evaluation of disease-resistant lines for resistance to pod borer, *Helicoverpa armigera*:** We evaluated 86 disease-resistant lines (identified to be resistant to wilt, Aschochyta blight, and/or gray mold) along with resistant and susceptible checks for resistance to the pod borer, *H. armigera* to identify disease-resistant lines with less susceptibility to pod borer for use in multiple resistance breeding programs. There were two replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative and maturity stages visually, pod damage (%), disease resistance score (1 = highly resistant, and 9 = highly susceptible), and grain yield. Damage by *H. armigera* larvae at the vegetative and maturity stages ranged from 2.0 to 6.0, and 3.5 to 8.0, respectively. Twelve lines (EC 516729, ICCV 89332, ICCV 96859, ICCV 96852, ICCV 93217, ICCV 96851, ICCV 04107, ICCV 05107, ICCV 05310, ICC 11322, and ICC 14364) showed lower disease susceptibility (disease incidence score <3.5 compared to 9.0 in ICC 506EB) and moderate levels of resistance to pod borer, *H. armigera* (damage rating <4.0 compared to a DR of 6.0 to 8.0 in ICC 3137). These lines will be useful for use in chickpea breeding programs for developing multiple pest-resistant genotypes in future.

CLL Gowda, HC Sharma and Suresh Pande

Output target 2011 6.1.1 CP Reference collection characterized for Helicoverpa resistance

Achievement of Output Target:
100%
Reference collection has been evaluated for resistance to pod borer for three seasons, and the lines showing resistance to pod borer and wilt complex have been identified for use in chickpea improvement.

Participating Countries:
India

Participating Partners:
None

Progress/Results:
Evaluated 300 chickpea reference accessions along with a resistant (ICC 506) and a susceptible (L 550) control cultivar for *Helicoverpa* resistance using detached leaf assay at the vegetative (30 days after seedling emergence) stage during 2008-2009 post rainy season. The terminal branches (5 to 7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation. A total of 34 (3.0) reference lines performed better than the resistant control cultivar ICC 506-EB for leaf feeding score. The best five reference lines were ICC 5878, ICC 6877, ICC 11764, ICC 16903, and ICC 18983(1.-2.3) for leaf-feeding score compared to resistant control cultivar ICC 506-EB (3.1). A total of 63 (37-60%) reference accessions had lower larvae survival rate compared to resistant control cultivars ICC 506-EB (63%). The best five accessions for least larvae survival rate were ICC 12537, ICC 9590, ICC 7819, ICC 2482, and ICC 4533 (37 – 47%). Larvae weight ranged from 1.2 to 13.1 mg larva^{-1}. A total of 47 reference accessions (<2.3 mg) showed lower larvae weight compared to resistant control cultivar ICC 506-EB (2.3 mg). ICC 16903, ICC 6877, ICC 3946, ICC 11746, and ICC 18983 (1.2 – 2.1 mg larva^{-1}) were the best five accessions for lower larvae weight.

HC Sharma, HD Upadhyaya and N Lalitha

Output target 2011 6.1.1 CP Physico-chemical mechanisms of resistance to Helicoverpa identified and nature of inheritance studied

Achievement of Output Target:
40%
Role of acid exidates in chickpea resistance to *Helicoverpa* has been elaborated, while work is continuing on understanding the role of iso-favolnoids in chickpea resistance to pod borer damage.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Role of organic acids in chickpea resistance to *Helicoverpa armigera*: To develop cultivars with resistance to insects, it is important to understand the role of different components associated with resistance to insects. Therefore, we characterized a diverse array of chickpea genotypes and for organic acid profiles in the leaf exudates that are associated with resistance to *H. armigera*. Chickpea leaf exudates contained five major organic acids, which were identified as malic acid, oxalic acid, acetic acid, citric acid, and fumaric acid. The high performance liquid chromatography (HPLC) profiles of the leaf exudates of nine chickpea genotypes showed that amounts of malic acid were negatively correlated with leaf feeding by *H. armigera* larvae at flowering and maturity, and with pod damage. Oxalic acid showed a negative association with leaf damage in detached leaf assay, while the amounts of acetic acid were negatively correlation with larval weight, and damage rating at flowering and maturity. Citric acid levels were negatively associated with damage rating at flowering. Implications of using HPLC profiles of organic acid leaf exudates to breed for resistance to *H. armigera* have been discussed.

HC Sharma, CLL Gowda and LV Narayanamma

Output target 6.1.2 CP Molecular markers for AB, BGM, and *Helicoverpa* resistance identified in chickpea

Activity 6.1.2.1 CP Mapping and marker-assisted breeding for diseases and insect resistance in chickpea

Milestone One inter-specific (C. arietinum x C. reticulatum) RIL populations for mapping Helicoverpa resistance QTLs developed 2009

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
None

Progress/Results
Inter-specific RIL mapping population from the cross ICC 3137 (susceptible) and IG 72953 (tolerant to *Helicoverpa*), currently in F_7 generation (239 RILs + 2 parents) is being advanced in the field. Vernalization treatment (keeping the germinated seeds at 4°C for one month prior to planting) is given in each generation for reducing the flowering time.

Special Project Funding:
None

<div align="right">PM Gaur, Shailesh Tripathi and CLL Gowda</div>

Output target 2011 6.1.2 CP QTLs for Helicoverpa resistance identified from Cicer arietinum x C. reticulatum RIL population

Achievement of Output Target:
75%
The interspecific population has been evaluated for three seasons and QTL analysis is in progress

Participating Countries:
India, Ethiopia, Kenya, Tanzania

Participating Partners:
Indian Institute of Pulses Research, India, Institute of Agricultural Research, Ethiopia, Kenya Agricultural Research Institute, Kenya

Progress/Results:
Evaluation of interspecific (*C. arietinum* x *C. reticulatum*) mapping populations for resistance to pod borer, *Helicoverpa armigera*:
Interspecific mapping population derived from ICC 4958 (*C. arietinum*) x PI 489777 (*C. reticulatum*) (128 lines along with resistant – ICC 506EB, susceptible - ICC 3137, commercial – ICCC 37, local – Annigeri, and Kabuli – L 550 checks, along the two parents) were evaluated for resistance to pod borer, *Helicoverpa armigera* using detaches leaf assay, and under natural infestation in the field. The material was evaluated for resistance to *H. armigera* using detached leaf assay in the laboratory at the vegetative (30 days after seedling emergence) and at the flowering stages. For this purposes the terminal branches (5 – 7 cm long) were brought to lab from the field, inserted in 3% agar-agar as a supporting medium, and infested with 10 neonate larvae in a 250 ml plastic cup. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

In the detached leaf assay during the vegetative stage, leaf damage rating varied from 2.33 to 8.03 in the mapping population (mean 5.15), 3.0 in PI 489777, 7.67 in ICC 4958, 3.0 in ICC 506 – the resistant check, and 5.33 in ICCC 37 – the susceptible check. The larval weight gain varied from 1.54 to 20.9 mg per larva in the mapping population (mean 4.32), 2.17 mg in PI 489777, 4.87 mg in ICC 4958, 3.98 mg in ICC 506, and 6.18 mg in ICCC 37. Under field conditions, days to first flower and days to 50% flowering varied from 26 – 108 and 32 to 116 days, respectively. Numbers of eggs during the vegetative stages varied from 0 – 5 eggs per plant, 0.70 eggs on PI 489777, 1.20 eggs on ICC 4958, 0.17 in ICC 506 and 0.90 eggs on ICCC 37; while during the flowering stage, there were 0 – 7.8 eggs per plant in the mapping population, 0.33 eggs on PI 48977, 1.0 on ICC 4958, 0.0 in ICC 506, and 0.1 on ICCC 37. Larval population varied from 0.0 – 2.8, 0.0 – 9.75, and 0.0 - 7.0 larvae per plant during the vegetative, flowering, and poding stages, respectively. During the vegetative phase, leaf damage rating varied from 2.0 to 8.03 in the mapping population, 6.0 in PI 489777, 6.97 in ICC 4958, 4.0 in ICC 506, and 3.5 in ICCC 37. Pod damage varied from 10.95 – 60.76% in the mapping population, 24.63% in PI 489777, 53.07% in ICC 4958, 12.56% in ICC 506, and 21.45% in ICCC 37. Grain yield in the mapping population varied from 20 – 3,750 kg ha^{-1}, indicating that some of the lines have high yield potential even under unprotected *Helicoverpa* infested conditions. The temperatures during February – March were unusually high, which influenced both the plant growth as well as the *H. armigera* infestation, and hence, the expression of the resistance to *H. armigera*. The results suggested that there is considerable variation in the progenies of the interspecific mapping population for resistance to *H. armigera*, and there is a possibility to identify interspecific derivatives with high levels of resistance to *H. armigera,* and QTLs associated with resistance to this insect.

Special Project Funding:
Tropical Legumes Project I - Gates Foundation

<div align="right">HC Sharma, PM Gaur and Rajeev Varshney</div>

Output target 6.1.3 CP Interspecific derivatives with resistance to AB, BGM and *Helicoverpa* developed

Activity 6.1.3.1 CP Inter-specific derivatives with resistance to *Helicoverpa* and BGM generated using wild *Cicer* from different gene pools

Milestone Wild relatives with diverse mechanisms of resistance to Helicoverpa identified 2009

Achievement of Output Target:
60%
Wild relatives with resistance to pod borer have been identified, and identification of resistance genes/mechanisms is in progress.

Progress/Results:
Evaluation of wild relatives of chickpea for different mechanisms of resistance to *Helicoverpa armigera*. Sixteen accessions of wild relatives of chickpea along with resistant (ICC 506) and susceptible (ICCC 37, ICC 3137, and Annigeri) checks were evaluated for resistance to *H. armigera* using detached leaf assay. There were three replications in a completely randomized design. Each terminal branch was infested with 10 neonate larvae in a 250 ml plastic cup, and the data were recorded on leaf feeding and larval weights at five days after infestation. At the vegetative stage, leaf damage rating in plants raised from vernalized seeds ranged from 0.67 to 3.50 in the wild accessions compared to 3.33 in ICC 506 and 5.81 in ICCC 37. The larval weights were lower than 2.0 mg per larva on IG 70006, IG 70018, IG 70032, and ICCW 117148 as compared to 2.67 mg on ICC 506 and 3.67 mg on ICCC 37. At the flowering stage, leaf damage rating in plants raised from vernalized seeds ranged from 2.33 to 6.67 in the wild accessions compared to 3.33 in ICC 506 and 3.67 in ICCC 37. The larval weights were lower than 1.5 mg per larva on IG 69979, IG 70022, IG 70032, IG 72953, PI 599066, and ICCW 117148 as compared to 1.49 mg on ICC 506 and 3.67 mg on ICCC 37.

<div align="right">HC Sharma</div>

Evaluation of perennial wild chickpeas for resistance to *Helicoverpa armigera*: Fifteen accessions of perennial wild relatives of chickpea along with the local perennial wild chickpea, *Cicer microphyllum*, were evaluated for resistance to *H. armigera* using detached leaf assay at the Regional Research Station, Himachal Agricultural University, Kukumseri, Himachal Pradesh, India. There were three replications in a randomized complete block design. Terminal branches were infested with 10 neonate larvae, and data were recorded on leaf feeding (1 = < 10% leaf area damaged, and 9 = > 80% leaf area damaged), larval survival, and larval weights at 5 days after initiating the experiment. Leaf damage rating varied from 1.7 in PI 599083 to 6.7 in PI 353625, and the accessions PI 599087, PI 599080, PI 599083, and PI 599085 suffered lower leaf feeding compared to PI 353625 (damage rating 6.7). The larval weights were significantly lower (< 0.0200 g) on PI 353625, PI 561078, PI 599087, PI 532928, PI 599083, PI 599085, W6-11516, PI 561084, and PI 561103 as compared that on PI 5999082 (0.0337 g).

<div align="right">HC Sharma and Sanjay Sharma</div>

Output target 2010 6.1.2 CP Interspecific derivatives (10) with enhanced resistance to AB, BGM, and Helicoverpa identified and made available to partners

Achievement of Output Target:
60%
Several breeding lines from interspecific crosses have been developed. These are being evaluated for resistance to diseases and pod porer.

Progress/Results:
Interspecific derivatives obtained from crossing wild *Cicer* species were evaluated for *H. armigera* resistance and were also evaluated for selected agronomic traits. The results are presented in Table 1. Lines with good canopy (more number of secondary and tertiary branches), early flowering and maturity and number of pods than in the control were observed. The lines also showed low *H. armigera* damage.

Table 6: Agronomic data for advanced generation interspecific derivatives of chickpea.

Line no.	No. of branches (Pri)	No. of branches (Sec)	No. of branches (Tert)	50% Flowering	Maturity at 75 (%)	No. of pods/plant (Mean)	Pod damage (%)	100 Seed wt.
Line 1	4.20	19.60	8.20	69.00	106.20	268.90	16.35	13.80
Line 2	8.20	19.80	5.80	72.50	105.80	160.10	15.00	13.81
Line 3	8.70	18.00	10.10	73.40	106.40	125.30	13.60	13.36
Line 4	8.50	22.70	8.10	73.20	105.00	171.70	17.44	15.16
Line 5	8.10	15.80	6.00	81.00	106.00	123.80	16.90	15.01
Line 6	9.90	15.20	3.80	74.80	104.80	184.30	17.39	14.61
Line 7	7.60	14.50	6.60	77.60	114.00	126.10	15.07	13.97
Line 8	9.60	18.10	5.60	79.00	108.20	124.50	22.40	14.88
Line 9	11.70	23.10	2.60	77.00	104.60	150.36	16.67	13.87
Line 10	11.00	18.40	4.20	78.00	109.60	145.40	12.40	13.78
Line 11	13.70	17.70	3.80	73.40	104.60	210.60	19.43	15.08
Line 12	12.80	19.50	4.40	77.80	104.50	158.60	20.13	16.71
Line 13	11.00	20.10	6.90	76.60	102.60	149.60	15.33	13.76

Line no.	No. of branches (Pri)	No. of branches (Sec)	No .of branches (Tert)	50% Flowering	Maturity at 75 (%)	No. of pods/plant (Mean)	Pod damage (%)	100 Seed wt.
Line 14	10.60	20.10	6.70	76.20	104.40	148.50	19.50	15.25
Line 15	12.10	23.30	7.50	78.80	110.40	142.10	12.00	13.84
Line 16	12.40	20.60	5.90	75.60	105.60	136.60	14.59	13.32
Line 17	13.80	23.20	9.30	78.60	109.20	150.70	13.24	15.59
Control	7.20	9.00	0.40	83.20	101.20	81.60	33.67	11.63
Mean	10.06	18.82	5.88	76.43	106.28	153.26	16.42	14.53
LSD (.05)	2.86	4.84	2.71	3.27	2.74	51.78	12.24	1.53
F Prob.	< .0001	<.0001	<.0001	< .0001	<.0001	<. 0001	<.0001	<.0002
CV (%)	10.14	27.94	49.56	4.73	2.83	36.73	53.01	11.65

Nalini Mallikarjuna, HC Sharma and PM Gaur

Output target 6.1.4 CP Promising transgenic events of chickpea with proven resistance to *Helicoverpa* available for introgression in locally adapted germplasm

Activity 6.1.4.1 CP Develop transgenic events of chickpea for resistance to *Helicoverpa armigera* and evaluate their performance under contained greenhouse and field conditions

Output target 2010 6.1.1 CP 1-2 promising Bt transgenic events identified and characterized for insect resistance in strip trial

Achievement of Output Target:
50 %
The detached leaf bioassays had shown promising results but since the expression observed with the *cry2Aa gene* is promising in comparison to *cry1Ac*, efforts are on to develop insect resistant chickpea by pyramiding with different *Bt* genes such as *cry1Abc, cry2A* and *cry2Aa*.

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
A total of 181 primary transgenic events have been produced in chickpea by using the *cry2Aa* (64 plants) and the *cry2A* (95 plants) and the *cry1ABC* (22 plants) genes through *Agrobacterium tumefaciens*-mediated genetic transformation of a popular chickpea cultivar, C 235. Molecular characterization using PCR was performed for all the plants carrying *cry2A* and *cry2Aa* genes to confirm their presence. Out of 159 independent putative transgenic plants tested , 90 plants showed the integration of the *Bt* gene. ELISA was also carried out for PCR confirmed transgenic plants carrying *cry2Aa* and *cry2A* genes for the confirmation of protein expression where 14 transgenic plants (8 plants with *cry2A* and 6 plants with *cry2Aa*) showed positive expression in ELISA analysis. Plants carrying *cry1Abc* will be screened using PCR analysis to confirm the gene of interest and ELISA will be carried out to check the expression of inserted genes.

Evaluation of putative transgenic chickpea plants for resistance to pod borer, Helicoverpa armigera*:* Insect bioassays were carried out under laboratory conditions for 11 transgenic events carrying the cry2A and cry1Ac genes, along with the non-transformed C 235, and the resistant check ICC 506. We evaluated 132 (108 from 9 cry1Ac transformed and 24 from cry2A transformed events) Bt-transformed chickpea plants, along with non-transformed C 235, and the resistant, ICC 506 and the susceptible, ICCC 37 as controls for resistance to pod borer, H. armigera under laboratory conditions. Terminal branches from each plant were bioassayed for resistance to H. armigera using detached leaf assay. Observations were recorded on leaf damage on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval survival, and larval weights after five days of feeding. The leaf damage rating in Bt-transformed plants varied from 2.0 to 9.0 as compared to 7.3 in C 235, 4.0 in ICCC 37, and 3.5 in ICC 506. Larval weights among the transgenic plants varied between 1.33 to 10.36 mg larva[-1], while on the non-transformed C 235, and ICCC 37 and ICC 506 it was 6.05, 4.05 and 2.87 mg larva[-1], respectively.

The results indicated that a few events showed some level of resistance to *Helicoverpa* under these bioassays and were advanced to further generations. An interesting observation was that the transgenic events carrying *cry2A* events showed less insect damage and larval survival in leaf bioassays when compared to plants carrying *cry1Ac* gene. However this needs further validation in future bioassays. Owing to the possible instability of *Bt* protein in ELISA analysis, efforts are being put to standardize the ELISA technique. As the expression with *cry1Ac* gene alone is not very promising, efforts are being put to develop insect resistant chickpea by pyramiding with different *Bt* genes such as *cry1Abc, cry2A* and *cry2Aa* by producing more number of transgenic events.

HC Sharma, MK Dhillon, Pooja Bhatnagar-Mathur and KK Sharma

Non-hybrid pigeonpea

Output target 6.1.1 PP About 5-6 pigeonpea varieties with stable resistance to *Fusarium* wilt, sterility mosaic and *Helicoverpa* made available to NARS

Activity 6.1.1.1 PP About 15 new genetically diverse germplasm sources/breeding lines resistant to wilt and sterility mosaic diseases identified

Milestone New knowledge on vegetable pigeonpea production synthesized, published and disseminated to partners 2009

Achievement of Output Target:
90%
The bulletin is under printing and will be distributed to NARS partners during 2010.

Participating Countries:
India

Participating Partners:
Indian NARS

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954
Progress/Results:
A comprehensive vegetable pigeonpea Information Bulletin entitled "Vegetable Pigeonpea– a High Protein Food for all Ages" is under printing. The manual provides excellent information on traits to be targeted for breeding vegetable pigeonpeas, quality parameters, vegetable pigeonpea germplasm, inheritance of important agronomic traits, seed production and maintenance, cultivation practices, and commercial processing of vegetable pigeonpeas. Copies of the information bulletin will be distributed to NARS partners.
<div align="right">KB Saxena and RK Srivastava</div>

Milestone About 100 germplasm/ advanced breeding lines screened for wilt and sterility mosaic disease resistance using different isolates and characterized for agronomic traits 2009

Achievement of Output Target:
100%

Participating Countries:
None

Participating Partners:
None

Special Project Funding:
None

Progress/Results:
Fusarium wilt and SMD resistance in advanced breeding lines: Sixty nine (17 further advanced selections from breeders material 2005-06 and 52 advanced breeding lines from ICRISAT 2007/08) were evaluated for combined resistance to FW and SMD under artificial epiphytotic conditions in pigeonpea wilt and sterility mosaic disease sick plot during 2008-09 at ICRISAT, Patancheru. Of the 17 further advanced selections, three lines (ICPLs 20105, 20125 & 99044) were asymptomatic (0% incidence) and 12 lines were resistant to both FW and SMD. However, five lines were asymptomatic and 11 resistant to FW while 9 were asymptomatic and 7 resistant to SMD. Among the 52 advanced breeding lines from ICRISAT 2007/08, twenty one lines were found asymptomatic (0% incidence) and 11 resistant showing <10% incidence to both FW and SMD.

Confirmation of FW and SMD resistance in breeding lines from cold store: Sixty three wilt and SMD resistant breeding lines were evaluated for combined resistance to FW and SMD under artificial epiphytotic conditions following standard field screening technique during 2008-09 at ICRISAT Patancheru. Out of 63 wilt and SMD resistant lines 16 were asymptomatic (0% incidence) and 11 resistant (0.1-10% incidence) to FW and SMD. For wilt, 17 lines were asymptomatic (0% incidence), 13 moderately resistant (0.1 – 10 % incidence) and 11 moderately resistant (10.1-20% incidence). However, 49 lines were asymptomatic (0% incidence), 6 resistant (0.1-10% incidence) and 4 moderately resistant (10.1-20% incidence) to SMD.
Suresh Pande and Mamta Sharma

Fusarium wilt and SMD resistance in AICRP-Pigeonpea trials: Out of 85 lines from All India Coordinated Research Project (AICRP) Pigeonpea, two were asymptomatic and 15 resistant to both FW and SMD. Two lines were found asymptomatic (0% incidence), 17 resistant (0.1-10% incidence) and 7 moderately resistant to FW. For SMD, 19 were found asymptomatic, 19 resistant and five moderately resistant.

Evaluation of Warangal (ANGRAU) lines for resistant to FW and SMD: Out of 32 lines from Warangal (ANGRAU), one line was found asymptomatic (0% incidence), one line resistant (0.1-10% incidence) and one line moderately resistant to both FW and SMD. One line was found asymptomatic (0% incidence), one resistant (0.1-10% incidence) and one moderately resistant to FW. For SMD, one line was asymptomatic, four resistant and four moderately resistant to SM.
<div align="right">Suresh Pande, Mamta Sharma and Collaborators</div>

Collection and purification of isolates of *Fusarium udum*: Thirty six isolates of *Fusarium udum* collected from 22 locations in 6 states in India were purified for the maintenance of virulence. Pathogenicity test was done using a common susceptible cultivar ICP 2376 following root dip technique under greenhouse conditions at ICRISAT-Patancheru. Koch's postulates were proved and single spore isolates were obtained following standardized mycological techniques.

Collection and purification of isolates of *Phytophthora drechsleri* f.sp. *cajani*: Isolations of *P. drechsleri* f.sp. *cajani* were made from freshly blighted seedlings and incubated at 25⁰ C in the incubators for seven days. Twenty one isolates of *P. drechsleri* f.sp. *cajani* collected from all the pigeonpea fields of ICRISAT, Patancheru were purified. Pathogenicity test was done using a susceptible cultivar ICP 7119 following spray inoculation under greenhouse conditions at ICRISAT-Patancheru. Koch's postulates were proved and pure cultures were obtained following standardized mycological techniques.

<div align="right">Suresh Pande and Mamta Sharma</div>

Milestone At least 5 new varieties with multiple disease and insect resistance made available to partners 2010

Achievement of Output Target:
70%
Lines with multiple disease resistance have been identified and will be further evaluated.

Participating Countries:
India

Participating Partners:
Indian NARS

Progress/Results:
The multiple disease resistant lines reported under 6.1.3 will be evaluated for resistance to *Helicoverpa* pod borer during 2010.

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954

<div align="right">KB Saxena, RK Srivastava, S Pande and HC Sharma</div>

Activity 6.1.1.2 PP Genetically diverse germplasm / breeding lines with resistance to *Helicoverpa* identified

Milestone Mechanisms of resistance to Helicoverpa in diverse germplasm characterized 2011

Achievement of Output Target:
40%
The leaf surface extracts in water and lyophilized plant tissue extracts in methanol extracts have been collected for HPLC – MS analysis.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
A set of lines has been characterized for oviposition non-preference and recovery resistance. Efforts are continuing to elaborate biochemical mechanisms of resistance to pod borer in pigeonpea.

Special Project Funding:
TMOP

<div align="right">HC Sharma</div>

Activities 6.1.1.3 PP Advanced generation interspecific derivatives with resistance to *Helicoverpa* and SMD using wild species from different gene pools developed

Milestone Physico-chemical mechanisms of resistance to Helicoverpa in wild relatives of pigeonpea identified for use in crop improvement 2009

Achievement of Output Target:
80%
Antixenosis and antibiotic mechanisms of resistance have been studied, and biochemical mechanism of resistance is under investigation.

Participating Countries:
India

Participating Partners:
IIPR, Kanpur

Progress/Results:
Feeding behaviour of pod borer, *Helicoverpa armigera* in relation to pod surface exudates of wild relatives of pigeonpea: We studied the feeding behaviour of pod borer, *Helicoverpa armigera* in relation to biochemical characteristics of the pod surface exudates of a diverse array of germplasm accessions belonging to wild relatives of pigeonpea. Larval feeding was greater on the pods of cultivated pigeonpea as compared to those of the wild relatives. The water and methanol washed pods of wild relatives were less preferred for feeding by the *H. armiger*a larvae than the unwashed pods. However, when the larvae were provided a choice between the unwashed and hexane washed pods, the larvae preferred to feed on the hexane washed pods. These results were also confirmed by impregnating the glass fiber discs with methanol or hexane extracts of the pods surface of wild relatives of pigeonpea. The results suggested that compounds on the pod surface extracted in hexane acted as antifeedants, while those extracted in methanol or water acted as phago-stimulants. The high performance liquid chromatography (HPLC) finger printing of the pod surface extracts in methanol or hexane indicated that there are both qualitative and quantitative differences in the compounds present on the pod surface of wild relatives of pigeonpea. Some of the components in HPLC

chromatograms were associated with feeding preference/non-preference of the third-instar larvae of *H. armigera.* The principal component analysis based on HPLC fingerprints of methanol and hexane extracts, and the biological interactions of *H. armigera* with different accessions indicated that wild relatives of pigeonpea exhibiting resistance to *H. armigera* are quite diverse, and the accessions with low amounts of phago-stimulants and high amounts of antifeedants may be selected for introgression of resistance genes into the cultivated pigeonpea to develop varieties with broad-based resistance to *H. armigera.*

HC Sharma

Milestone Ten interspecific derivatives from different Cajanus species belonging to different gene pools with resistance to Helicoverpa identified for use in pigeonpea improvement 2011

Achievement of Output Target:
70%
Interspecific derivatives with resistance to *Helicoverpa* identified and would be evaluated again during 2010 and 2011.

Participating Countries:
ICRISAT, India

Participating Partners:
ICRISAT scientists

Progress/Results:
Secondary gene pool
Cajanus acutifolius: Lines with resistant score (2-4, on a scale of 1-9) selected from 2007 and 2008 screening experiments were grown in an unprotected field for Helicoverpa armigera screening. 24 lines were selected which had low H. armigera damage. Lines with low to nil H. armigera damage and high seed weight continued to show the traits. One of the lines with higher seed weight (16 to 19 gm/100 seed weight), high seed number, in addition to low H. armigera damage is presented in Fig. 6.2.
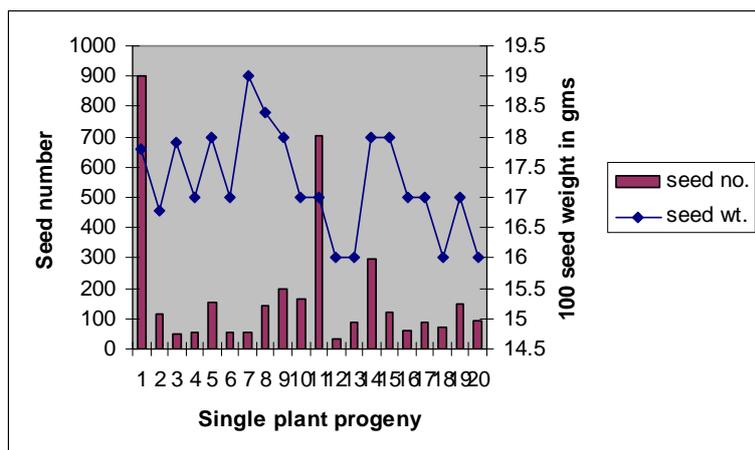

 Figure 6.2. High seed weight with low *H. armigera* damage progeny derived from *C. acutifolius*.

Cajanus scarabaeoides: To transfer the pod borer resistance from wild to cultivated pigeonpea, crosses involving cultivated (*C. cajan*) accessions ICP 26, ICP 28, ICP 14770 and *C. scarabaeoides* were attempted. ICP 28 x ICPW 94 cross was found as promising. Fresh crosses were attempted between ICPW 94 and ICP 28 during 2007-08. All F1s' were grown and helicoverpa resistant single plants were harvested. During 2008-09, F2 generation was grown. During 2009-10, 52 F9 and 210 F2 *Helicoverpa* resistant single plant progenies are being evaluated for agronomic superiority and *Helicoverpa* resistance

Tertiary gene pool
C. platycarpus: Twenty seven lines (BC_4F_5) were used as demonstration block and screened for various traits including resistance for *H. armigera*. Three lines did not show any damaged pods and were scored as highly resistant. In these, two lines had higher pod number compared to pigeonpea cultivars which were used as controls. Another seven lines had less than 2% damaged pods. Five lines had an average of 900 pods compared to 350 in the cultivated control. Lines with high pod number and low *H. armigera* damage will be selected for further studies.

Nalini Mallikarjuna, HD Upadhyaya and HC Sharma

Evaluation of interspecific derivatives of pigeonpea for resistance to *Helicoverpa armigera*: We evaluated 107 biparental progenies of ICPW 94 x ICP 28 for resistance to pod borer, *H. armigera*. Data were recorded on oviposition, larval density, and pod borer damage. The first flush was completely damaged by heavy onslaught of pod borers, *H. armigera* and *Maruca vitrata*. In the second flush, pod damage ranged from 3.33 to 90.0% in tagged inflorescences and 11.43 to 100% in the pod samples collected from plants selected at random. Eleven lines showed <40% pod damage as compared to 41.78% pod damage in ICPL 332.

HC Sharma and HD Upadhyaya

Milestone New sources of SMD resistance generated through the utilization of wild Cajanus 2010

Achievement of Output Target:
60%
Interspecific derivatives resistance to Bangalore race of SMD identified and resistance to Patancheru race needed to be confirmed.

Participating Countries:
India

Participating Partners:
UAS-Bangalore

Progress/Results:
From the Interspecific derivatives derived from *Cajanus acutifolius* were identified as resistant to Patancheru isolate of SMD, two lines showed resistance to Bangalore isolate, the most virulent isolate of SMD. Similarly two lines derived from *C. platycarpus* have shown resistance to Bangalore isolate of SMD, but these have not been verified for Patancheru isolate. All the four lines will be re-screened again for Bangalore isolate of SMD.

Special Project Funding:
None

<div align="right">Nalini Mallikarjuna and Byre Gowda-UAS, Bangalore</div>

Output target 6.1.2 PP Promising transgenic events of pigeonpea with proven resistance to *Helicoverpa* available for commercialization and introgression in locally adapted germplasm

Activity 6.1.2.1 PP Develop transgenic events of pigeonpea for resistance to *Helicoverpa armigera* and evaluate their performance under contained greenhouse and field conditions

Output target 2010 6.1.2 PP 1-2 promising Bt transgenic events of pigeonpea identified in strip trials

Achievement of Output Target:
75 %
Nearly ten plants with biological activity have been selected for further bioassays to confirm the level of resistance.

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results**:**
Over 50 transgenic events of pigeonpea were developed with different cry genes, cry1Aabc and cry2Aa and transferred to the glass house and screened. The molecular characterization for these events was carried out to look at the introduction and expression of the transgenes. A total of 88 events that were previously produced with the synthetic cry1Ac gene were further evaluated. The transgenic plants have been analyzed for the transgene by PCR, and also characterized for expression of the Bt gene using ELISA. Based on the expression in ELISA 11 events were carried further for the insect bioassays.

Evaluation of putative transgenic pigeonpea plants for resistance to pod borer, Helicoverpa armigera:
279 plants were evaluated (33 plants from 11 events (6 replicates each) in set I, 96 plants from 7 events in set II (12 replicates) , and 150 plants from 3 events (30 replicates each) in set III) cry1Ac transformed pigeonpea plants along with non-transformed ICPL 88039, the resistant check, ICPL 332, and the susceptible check, ICPL 87 for resistance to pod borer, H. armigera under laboratory conditions. Three trifoliates from each plant were bioassayed for resistance to H. armigera using detached leaf assay. Observations were recorded on leaf damage on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval survival, and larval weights after five days of feeding. In the set I, leaf damage rating in Bt-transformed plants varied from 3.44 to 5.39, and 6.60, 7.0, and 4.0 in the non-transformed genotypes ICPL 88039, ICPL 87, and ICPL 332, respectively. Larval weights varied between 0.32 to 0.75 mg larva^{-1} in Bt-transformed plants, while on non-transformed ICPL 88039, ICPL 87, and ICPL 332, the larval weights were 1.46, 2.45, and 1.81 mg larva^{-1}, respectively. None of the plants were ELISA positive. In the set II, leaf damage rating in Bt-transformed plants varied from 4.6 to 6.8, and 6.60, 7.0, and 5.0 in the non-transformed genotypes ICPL 88039, ICPL 87, and ICPL 332, respectively. Larval weights varied between 0.73 to 1.79 mg larva^{-1} in Bt-transformed plants, while on non-transformed ICPL 88039, ICPL 87, and ICPL 332, the larval weights were 1.46, 1.99, and 1.54 mg larva^{-1}, respectively.

In the set III, leaf damage rating in Bt-transformed plants varied from 3.5 to 5.6, and 5.2, 4.3, and 5.0 in the non-transformed genotypes ICPL 88039, ICPL 87, and ICPL 332, respectively. Larval weights varied between 0.42 to 0.88 mg larva^{-1} in Bt-transformed plants, while on non-transformed ICPL 88039, ICPL 87, and ICPL 332, the larval weights were 0.58, 0.55, and 0.58 mg larva^{-1}, respectively. None of the plants were ELISA positive. Based on the bioassay results, a total of 17 plants were selected for flower and pod bioassay. The flower bioassay of the selected events was done in three replications, along with the non-transformed control ICPL 88039. No significant differences were observed in larval survival and larval weights of H. armigera larvae fed on flowers of Bt-transformed events and the non-transformed control pigeonpea, ICPL 88039. Leaves and flowers of none of these selected plants were found ELISA positive. The pod bioassay was not done due to asynchronous pod set and non-availability of enough pods for bioassay in the selected events.

Since, the events that were advanced generations showed reduction in the Bt expression levels in ELISA, so efforts are underway to look at the expression of the pure protein. Efforts have been made to express the cry genes in the bacterial expression system for over expressing the toxin that can be further purified and can be used for antibodies production as well as for generating the preliminary biosafety data. Attempts are also being made for pyramiding both cry1Ac and cry2Aa genes in a single construct for better expression of the bt protein. Efforts are

also underway to standardize the Q-PCR for the early screening of the transgenic events for the copy number and zygosity. Efforts are on to develop more number of transgenic events with these genes.

HC Sharma, MK Dhillon, Pooja Bhatnagar – Mathur and KK Sharma

Output target 6.1.3 PP Twenty medium-long duration vegetable type pigeonpea germplasm/breeding lines made available

Activity 6.1.3.1 PP Evaluation and selection of large podded medium – long duration germplasm and breeding lines for use as vegetable

Output target 2011 6.1.3 PP 10-15 genetically diverse large-seeded vegetable type breeding populations and lines for further selection developed

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
Indian NARS

Progress/Results:
During 2009 rainy season, a total of 33 diverse vegetable type lines (ICPL 20279 to 20293, ICPL 12026, ICPL 12176, ICPL 12043, ICPL 12023, ICPL 12024, ICPL 12037, ICPL 12792, ICP 9158, ICPL 11440, ICP 1283, ICPL 13087, ICP 1514, ICPL 13050, ICPL 13258, ICPL 12796, ICPL 13255, ICPL 13330, ICPL 13092) were grown in two sets at ICRISAT Patancheru. The first set was gown in the disease nursery, and second set in disease free plot under net for obtaining genetically pure seeds. Out of these 33 lines, six lines were highly resistant (disease score 0) to *Fusarium* wilt (ICPL 12023, ICPL 12037, ICPL 11440, ICPL 13087, ICPL 13258, and ICPL 13092), while five were highly resistant (disease score 0) to sterility mosaic (ICPL 12043, ICPL 9159, ICPL 12823, ICP 1514, and ICPL 13092). Due to heavy water logging, there was also natural screening for *Phytophthora* blight. Two lines ICPL 12037 and ICPL 13092 were highly resistant (no disease incident even on a single plant) to all the three (*Fusarium* wilt, sterility mosaic, and *Phytophthora* blight) diseases.

RK Srivastava and KB Saxena

Sorghum

Output target 6.1.1 SO High yielding grain, forage, and sweet sorghum lines with resistance to insect pests and diseases developed

Activity 6.1.1.1 SO Selecting high biomass forage and sweet sorghum lines with resistance to shoot pests and foliar diseases, and grain sorghum with tolerance to grain mold

Milestone Sweet sorghum lines (5) with high grain yield and shoot fly resistance developed for postrainy season adaptation 2010

Achievement of Output Target:
75%
The promising lines selected will be tested in replicated trials next season.

Participating Countries:
India

Participating Partners:
Partners of Sorghum Hybrid Parent Research Consortium, Directorate of Sorghum Research

Progress/Results:
Advanced Varietal Trial (AVT): From the preliminary varietal trial evaluated during 2008 rainy season, 12 varieties were selected based on grain yield and evaluated in AVT during 2008 postrainy season in a three-replicated RCBD along with the controls SPV 1616 and ICSV 112. Compared to the best performing control ICSV 112 (4.96 t ha^{-1}), one variety was numerically superior by 4% and six varieties (3.88 to 4.71 t ha^{-1}) were on par with it. The grain luster among these seven lines ranged from 2.0 to 3.0 (ICSV 112: 3.0), grain size (g 100^{-1} grains) ranged from 2.13 to 3.04 (ICSV 112: 2.34), days to flowering ranged from 76 to 89 days (ICSV 112: 75 days), plant height ranged from 1.9 to 2.3 m (ICSV 112: 1.7 m).

Evaluation of sweet sorghum elite varieties and R-lines for shoot fly and aphids resistance: Twenty eight elite varieties and restorers along with a shoot fly resistant variety (IS 18551), a susceptible variety (Swarna) and commercial variety (SSV 84) checks were evaluated for shoot fly resistance in a randomized complete block design with three replications during postrainy season 2008. Data were recorded on percentage plants with shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence in the test entries ranged from 1.1 to 32.8%, compared to 2.2% deadhearts in the resistant check, IS 18551, and 16.0% in swarna. Two varieties, SPV 1411and ICSV 700 showed significantly lower susceptibility by 41% for shoot fly. Three lines SP 4495, ICSV 93046, and Moulee showed resistance to both shoot fly, and stem borer (*Chilo partellus* and *Sesania inferens*) damage. Sixteen of these lines showed moderate susceptibility to sugarcane aphid, *Melanaphis sacchari* (damage rating of <4.0) compared to 7.0 in Swarna – the susceptible check, but the overall aphid incidence was quite low due to very high temperatures.

BVS Reddy, P Srinivasa Rao and HC Sharma

Evaluation of advanced and segregating material for resistance to shoot fly during the postrainy season: Sixty-six advanced lines along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance. Fifteen lines suffered <10% deadheart incidence compared to 6.24% in the resistant check, IS 18551, and 30.11% in Swarna. Some of these lines also showed less susceptibility to stem borer damage and exhibited good recovery resistance. In another trial, 80 advanced lines along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance. Twenty-five lines suffered <10% deadheart incidence compared to 12.18% in the resistant check, IS 18551, and 30.00% in Swarna. Some of these lines also showed less susceptibility to stem borer damage, 15 lines exhibited good recovery resistance.

HC Sharma, Ashok Kumar and BVS Reddy

Evaluation of sweet sorghum elite lines for resistance to shoot fly: During the postrainy season, 31 sweet sorghum lines were evaluated for shoot fly, *A. soccata* resistance, including the resistant (IS 18551), susceptible (Swarna), and commercial (SSV 84 and CSH 22SS) checks. There were three replications in a randomized complete block design. Data were recorded on percentage plants with shoot fly deadhearts at 21 days after seedling emergence. Six lines suffered less shoot fly damage (<10% shoot fly deadhearts compared to 16.17% in Swarna and 38.44% in SSV 84), of which three lines SP 4495, ICSV 93046, and Moulee showed resistance to both shoot fly, and stem borer (*Chilo partellus* and *Sesania inferens*) damage. Sixteen of these hybrids showed moderate susceptibility to sugarcane aphid, *Melanaphis sacchari* (damage rating of <4.0) compared to 7.0 in Swarna – the susceptible check, but the overall aphid incidence was quite low due to very high temperatures.

HC Sharma

Output target 2011 6.1.1 SO Ten sweet sorghum lines with high biomass and resistance to shoot pests and foliar diseases developed

Achievement of Output Target:
75%
Several promising lines with high biomass and resistance to shoot pests and foliar diseases have been developed and these will be further evaluated.

Participating Countries:
India.

Participating Partners:
Partners of Sorghum Hybrid Parent Research Consortium.

Special Project Funding:
ICRISAT-IFAD biofuels project and Partners of Sorghum Hybrid Parent Research Consortium.

Progress/Results:
Evaluation of varieties/restorers for resistance to shoot fly tolerance: A total of forty six sweet sorghum varieties/restorers were evaluated for shoot fly tolerance during the rainy season, 2009 with *swarna* as susceptible check and IS18551 as resistant check in RCBD. Twenty eight varieties/restorers shown 1 - 57% less shoot fly dead hearts than susceptible check swarna (86%) . Fifteen among them recorded have recorded significantly less dead hearts by 3 to 53% (SSV 84: 77%).

Evaluation of hybrids and their parents for resistance to shoot fly and aphids resistance: Thirty varieties/restorers were evaluated in 2009 rainy season for shoot fly and aphids resistance. Seventeen varieties/restorers have shown 5 - 42% less shoot fly dead hearts (55 – 91%) than control (SSV 84: 96%) and 7 lines among them have aphid score 4 (SSV 84: 5).

P Srinivasa Rao, HC Sharma, BVS Reddy and A Ashok Kumar

Evaluation of sweet sorghum varieties for anthracnose and grain mold resistance: A total of 46 R-lines/varieties were evaluated for grain mold and anthracnose resistance in the grain mold and anthracnose nurseries during rainy season 2009. Grain mold evaluation was done under natural infection and anthracnose through artificial inoculation. The experiment was conducted in a RCBD with 3 replications, 1 row of 2 m length as plot size. The sprinkler irrigation was provided twice a day for 30 min each on rain-free days from flowering to physiological maturity to provide high humidity (>90%RH) essential for mold development. The grain mold and anthracnose scores were recorded at physiological maturity (PM) using a 1 to 9 scale.

Grain mold resistance: Twenty three R-lines were resistant to grain mold. Thirteen of the 46 R-lines were also screened during 2008. Based on two years grain mold scores, two lines ICSR 93034 and NSS254 were resistant in both the screens indicating stable resistance in these lines to grain mold.

Anthracnose resistance: Ten R-lines/varieties were resistant and 30 moderately resistant to anthracnose. Of 46 lines, 19 were common in 2008 and 2009 screens. Of the 19 lines, seven lines (64DTN, ICSR 93034, ICSV 93046, IS 23526, NSS 254, RSSV 106 and S 35) were resistant across years indicating stable resistance in these lines to anthracnose. Two R-lines ICSR 93034 and NSS 254 were resistant to both grain mold and anthracnose.

Blight and rust: The same set of 46 R-lines/varieties is being evaluated for leaf blight and rust resistance in the leaf blight nursery during postrainy season 2009. The sweet sorghum lines were whorl-inoculated with infested sorghum grain (grains colonized by *Exserohilum turcicum*) 30 days after seedling emergence, and high humidity was maintained through overhead sprinklers twice a day on rain free days. Leaf blight severity will be recorded at soft-dough stage. For rust resistance, the lines will be evaluated under natural infection by rust fungus.

BVS Reddy, RP Thakur, P Srinivasa Rao and Rajan Sharma

Activity 6.1.1.2 SO Developing QTL mapping populations for economic yield components of sweet sorghum productivity

Output target 2010 6.1.1 SO Two F7 sorghum RIL mapping populations (350 each) available for genotyping and assessment of yield, quality, and sugar content

Achievement of Output Target:
75%
Lack of adequate irrigation water at the start of the 2008 *kharif* season (where late sowing resulted in unacceptably high level of natural selection against susceptibility to sorghum shoot fly) and at the start of the 2009 *kharif* season (where, having learned from the previous year's experience we refused to sow the materials once the date for escape from shoot fly infestation had passed) for advancing nurseries for inbreeding of RIL progeny sets has resulted in us falling one generation behind the timeline required to meet this output target. Further, as the IFAD project has specifically withdrawn support for advance of RIL progenies targeting sweet sorghum productivity traits, we do not have the additional operational resources that would be required to advance the RIL sets more rapidly under protected conditions in the polyhouse.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
RIL mapping populations of >400 progenies each, based on crosses (BTx623 × S 35; not sweet, salinity tolerant, moderate biomass x sweet, salinity sensitive, moderate biomass) and (ICSV 93046 × S 35, sweet, salinity tolerant, high biomass x sweet, salinity sensitive, moderate biomass) were advanced to F4 seed progenies during the 2007/08 postrainy season. Attempts to advance these a further generation <u>without selection</u> during the 2008 rainy season failed due to uncontrollable insect pest pressure (shoot fly) when sowing was delayed due to the late onset of the rains at Patancheru and lack of adequate irrigation water to permit timely sowing. The F4 progenies were resown for advance to F5 (by modified single seed descent) during the 2008/09 postrainy season. Despite losing one generation this year, we are still on track to be able to produce F6 RILs of these two populations by the end of the 2010 summer season, and have a fair chance of meeting the objective of having F7 RILs available for genotyping and phenotyping at the end of 2010.

During summer 2009, 390 F4 progenies derived from F1 plant [BTx623-P7 (not sweet, salinity tolerant, moderate biomass) × S 35-P3 (sweet, salinity sensitive, moderate biomass)]-P17 were advanced to F5 (>90% by selfing) by modified single-seed descent, and F5 seed harvested from these were then sown for a further generation advance (to F6 seed) during the *rabi* season of 2009-10. Thus by the end of 2010 we expect to have reached, at most, the F7 seed generation in RIL development from this cross (assuming that we can successfully advance these materials during the kharif season of 2010, and avoid failures similar to those experienced in 2008 and 2009).

Similarly, during summer 2009, 453 F4 progenies derived from F1 plant [ICSV 93046-P1 (, sweet, salinity tolerant, high biomass) × S 35-P4 (sweet, salinity sensitive, moderate biomass)]-P15 were advanced to F5 (>90% by selfing) following modified single-seed descent, and F5 seed harvested from these were then sown for a further generation advance (to produce F6 seed) during the *rabi* season of 2009-10. Thus by the end of 2010 we expect to have reached, at most, the F7 seed generation in RIL development from this cross (assuming that we can successfully advance these materials during the kharif season of 2010, and avoid failures similar to those experienced in 2008 and 2009).

Seed multiplication of these two F7 RILs for subsequent use in field trials, and DNA isolation for use in linkage map data generation, can then take place during the 2009/10 postrainy season, provided that operational resources for these activities can be identified.

Special Project Funding:
Until this year, this was supported, in part, with funding from IFAD.

CT Hash

Activity 6.1.1.3 SO Developing high yielding sorghum lines with grain mold resistance for rainy season, and shoot fly resistance for postrainy season

Output target 2010 6.1.1 SO Genetically diverse sorghum breeding lines (10) for high yield and large grain size with resistance to grain mold made available to partners

Achievement of Output Target:
75%
R lines with panicle grain mold rating (PGMR) of <5.0 have been identified and efforts are being made to identify new sources of resistance.

Participating Countries:
India

Participating Partners:
Partners of Sorghum Hybrid Parents Research Consortium

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Progress/Results:
Evaluation of advanced and segregating material for resistance to grainmold: Forty three advanced R-line progenies in RCBD (3 reps) were evaluated for grain mold resistance in screening block and for grain yield assessment in breeding block in 2009 rainy season. Grain mold severity was recorded at physiological maturity on a 1−9 scale (1= 0 to <1% mold infection − highly resistant and 9= 76−100% molded grains on a panicle- highly susceptible. The panicle grain mold rating (PGMR) score in these progenies ranged from 4.2 to 7.1 in screening block and grain yield ranged from 0.72 to 3.39 t ha^{-1} in breeding block. The control R-line - CSV 4 showed a PGMR score 7.0

with a grain yield of 2.68 t ha^{-1}. Two R-lines 61205-4 and 60719-1 showed a grain yield of 3.39 t ha^{-1} and 3.21 t ha^{-1} significantly (by 11 to 18%) higher grain yield than CSV 4 with PGMR score 6.6 and 5.3 less than CSV 4.

Planted new sources (10) for grain mold resistance from germplasm and high yielding B-lines to develop F$_1$s in the 2009 post rainy season. The progenies with restorer reaction and bold grain identified in 2009 post rainy season will be evaluated for GM/SF screenings in 2010 rainy and post rainy seasons.

<div align="right">Rajan Sharma, Ashok Kumar and BVS Reddy</div>

Evaluation of advanced and segregating material for resistance to shoot fly, *Atherigona soccata*: Sixty-six advanced lines along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance during postrainy season 2008. Fifteen lines suffered <10% deadheart incidence compared to 6.24% in the resistant check, IS 18551, and 30.11% in Swarna. Some of these lines also showed less susceptibility to stem borer damage and exhibited good recovery resistance. In another trial, 80 advanced lines along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance. Twenty-five lines suffered <10% deadheart incidence compared to 12.18% in the resistant check, IS 18551, and 30.00% in Swarna. Some of these lines also showed less susceptibility to stem borer damage, 15 lines exhibited good recovery resistance.

Thirty four varieties/R-lines in RCBD (3 reps) trial were evaluated for shoot fly resistance in screening block in the 2009 rainy season. The varieties ranged from 39 to 97% for shoot fly dead hearts and control Swarna showed 78% dead hearts. Eight lines showed 39 to 55% dead hearts significantly less by 6 to 33% than Swarna. The same set is being evaluated for postrainy season adaptation and shoot fly resistance in the 2009 postrainy season.

<div align="right">HC Sharma, Ashok Kumar and BVS Reddy</div>

Output 6.2. Annually knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of mandate crops and associated capacity building made available to partners internationally

Groundnut

Output target 6.2.1 GN Groundnut varieties with tolerance to drought and salinity developed using conventional and biotechnological approaches

Activity 6.2.1.1 GN Identify high yielding groundnut varieties tolerant to drought

Output target 2010 6.1.1 GN 6-8 high yielding dual-purpose groundnut varieties in a range of maturity groups with resistance to chronic biotic constraints available for release and commercialization (collaboration with ILRI)

Progress under this section has already been reported in 6.2.1 section, MTP output 2, 2009

<div align="right">SN Nigam</div>

Milestone 8 – 10 new advanced lines with resistance to drought tested in partner countries 2009

Achievement of Output Target:
100%

Participating Countries:
Argentina, Ghana, India, Philippines, South Africa, Eritrea and UAE.

Participating Partners:
NARS

Progress/Results:
One set of international groundnut varietal trial each to Eritrea, India and South Africa and 122 advanced breeding lines and 8 segregating populations were supplied to NARS in Argentina, Ghana, India, Philippines, South Africa, Eritrea and UAE.

New crosses: During 2008/09 postrainy and 2009 rainy seasons, 25 new crosses were made to generate populations for selection for resistance for drought along with high pod yield in agronomically desirable backgrounds. ICR # 13, 37, JAL # 15, 42, JUG 1, ICGV # 07225, 07043, 07165, 07173, 07193, 07286, 08141, 07210, 06142, and ICG 1236, were the drought and *A. flavus* tolerant breeding lines used in hybridization program.

Breeding populations: During the 2008/09 postrainy season, 156 F$_2$-F11 bulks and 69 plant progenies were sown under imposed mid-season stress condition for further evaluation. From these, 171 bulks and 214 single plants were selected. Of these, 44 in advanced generations were identified for inclusion in replicated yield trials The most promising selections came from (ICGV 94358 x ICG 1891), (ICG 8230 x ICGX 000047), (ICG 5341 x ICGV 03115), and (ICGX 000027 x ICGX 000049) crosses. During the 20009 rainy season, 137 F$_2$- F$_{12}$ bulks and 214 plant progenies were sown under rain-fed conditions for further evaluation. From these, 261 bulks and 86 single plants were selected. The most promising selections came from (ICG 5341 x ICGX 000049), (ICGX 010041 x ICGX 000047), and (ICGX 000027 x ICGX 000052).

Yield trials: Results of yield trials conducted in the 2008 rainy season (not reported in the 2008 Archival report), are discussed here. In the 2008 rainy season two hundred and four advanced breeding lines including controls in six replicated trials (Preliminary, Advanced and Elite trials in Spanish and Virginia types) were evaluated under rainfed conditions. Four elite and advanced trials were also sown with full irrigation. Similarly in the 2008/09 postrainy season same set of experiments were grown under irrigation/imposed mid season stress conditions. The salient findings are as below-

2008 rainy season:
- Out of 104 test entries only 2 in irrigation and 10 in rainfed condition produced significantly higher pod yield than the best control.
- In Preliminary Trial (Spanish) grown under full irrigation condition, two lines ICGV 08139 (5.5±0.29 t ha^{-1} pod yield, 62% shelling outturn, and 33 g HSW) and ICGV 08141 (5.1t ha^{-1} pod yield, 67% shelling outturn, 38 g HSW) significantly out-yielded the highest yielding drought resistance control ICGV 02266 (4.2 t ha^{-1} pod yield, 64% shelling outturn, and 37 g HSW).
- In Advanced Trial (Spanish) grown under rainfed condition, 10 out of 22 test lines (5.3-4.5±0.14 t ha^{-1} pod yield) gave significantly higher pod yield than the highest yielding drought resistance control ICGV 02266 (4.1 t ha^{-1} pod yield, 64% shelling outturn, 40 g HSW, SPAD Chlorophyll Meter Reading (SCMR, 60 DAS) 38, and SCMR (90 DAS) 27). The best entry in the trial was ICGV 07270 (5.3 t ha^{-1}pod yield, 64% shelling outturn, 31 g HSW, SCMR (60 DAS) 42, and SCMR (90 DAS) 38) followed by ICGV 07269 (4.8 t ha^{-1} pod yield, 62% shelling outturn, 38 g HSW, SCMR (60 DAS) 42, and SCMR (90 DAS) 32).

2008/09 postrainy season:
- Out of 184 test entries only in irrigation condition 10 lines produced significantly higher pod yield than the best control.
- In Elite Trial (Spanish) grown under full irrigation condition, ICGV 07223 (6.8±0.33 t ha^{-1} pod yield, 68% shelling outturn, 55 g HSW, 55% oil content, and 23% protein content) significantly out-yielded the highest yielding drought resistance control ICGV 02266 (5.5 t ha^{-1} pod yield, 70% shelling outturn, 64 g HSW, 52% oil content, and 24% protein content).
- In Elite Trial (Virginia) grown under full irrigation condition, 6 out of 11 test lines (6.8-5.6±0.26 t ha^{-1} pod yield) gave significantly higher pod yield than the highest yielding drought resistance control ICGV 87846 (4.5 t ha^{-1} pod yield, 70% shelling outturn, 65 g HSW, 55% oil content, and 23% protein content). The best entry in the trial was ICGV 07246 (6.8 t ha^{-1}pod yield, 68% shelling outturn, 49 g HSW, 56% oil content, and 20% protein content) followed by ICGV 07247 (6.4 t ha^{-1} pod yield, 69% shelling outturn, 51 g HSW, 56% oil content, and 22% protein content).
- In Advanced Trial (Spanish) grown under full irrigation condition, ICGV 07286 (6.1±0.50 t ha^{-1} pod yield, 64% shelling outturn, 37 g HSW, 54% oil content, and 23% protein content) significantly out-yielded the highest yielding drought resistance control ICGV 00350 (4.7 t ha^{-1} pod yield, 74% shelling outturn, 56 g HSW, 53% oil content, and 23% protein content).
- In Advanced Trial (Virginia) grown under full irrigation condition, three lines (6.5-6.3±0.45 t ha^{-1} pod yield) gave significantly higher pod yield than the highest yielding drought resistance control ICGV 87846 (5.0 t ha^{-1} pod yield, 66% shelling outturn, 72 g HSW, 50% oil content, and 23% protein content). The best entry in the trial was ICGV 07296 (6.5 t ha^{-1}pod yield, 70% shelling outturn, 54 g HSW, 55% oil content, and 22% protein content)

*2009 rainy season***:**
- One hundred and twenty seven advanced breeding lines including controls were evaluated for yield and other agronomic traits in six replicated trials. Elite and Advanced trials were grown under irrigated and rain-fed conditions. The trial data are being analyzed.

SN Nigam

Milestone Performance of 3-4 dual-purpose varieties validated on-farm in drought prone areas 2009

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
RDT and DoA, Karnataka

Progress/Results:
A dual purpose variety ICGV 91114 was released in Karnataka for cultivation in drought-prone areas of the state.

SN Nigam

Output target 2010 6.2.1 GN One to two farmer-preferred drought tolerant varieties identified in partner countries

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
ICAR and SAU's

Progress/Results:
Drought tolerant varieties ICR 48 and ICGV 91114 were released and ICGV 00350 and ICGV 87846 were identified for release in India.

SN Nigam

Milestone Knowledge of inheritance of traits associated with drought tolerance in three crosses gained and appropriate breeding strategy devised 2010

Achievement of Output Target:
100%

Participating Countries:
None

Participating Partners:
None

Progress/Results:
- Parent and different filial generations are now available for the experiment under normal and imposed drought conditions in the 2010/11 postrainy season.
- During the 2009 rainy season, 862 F_8 RILs of 3 crosses (ICGS 76 x CSMG 84-1, 272 RILs; ICGS 44 x CSMG 84-1, 134 RILs; ICGS 44 x ICGS 76, 456 RILs) were sown for seed multiplication for further studies.

Special Project Funding:
TL II and The OPEC Fund

<div align="right">SN Nigam</div>

Milestone Range of variation for key physiological traits assessed in breeding materials and varieties from the breeding program 2010

Achievement of Output Target:
50%
We have the lysimetric facility working now for groundnut and have evaluated some materials. We now have contrasting materials (germplasm) from field based assessment, which would give a good range of contrast to assess traits that matter for yield under intermittent drought
Participating Countries:
Mali, Malawi, India, Senegal, Tanzania, Niger

Participating Partners:
NARS of the countries mentioned above

Progress/Results:
Transpiration efficiency (TE) is an important trait for drought tolerance in peanut (*Arachis hypogaea* L.). The variation in TE was assessed gravimetrically using a long time interval in nine peanut genotypes (Chico, ICGS 44, ICGV 00350, ICGV 86015, ICGV 86031, ICGV 91114, JL 24, TAG 24 and TMV 2) grown in lysimeters under well-watered and drought conditions. The transpiration was measured by regular weighing of the lysimeters whose soil surface was mulched with a 2-cm thick layer of polythene beads. TE in the nine genotypes used varied from 1.4 to 2.9 g kg^{-1} under well watered and 1.7 to 2.9 g kg^{-1} under drought conditions, showing consistent variation for TE among the nine genotypes. A higher TE was found in ICGV 86031 in both well-watered and drought conditions and the lower TE was found in TAG-24 under both the water regimes. Although the total water extraction differed little across the genotypes, the pattern of water extraction from the soil profile varied among the genotypes. High water extraction within 24 days following stress imposition was negatively related to pod yield ($r^2 = 0.36$), and negatively related to water extraction during a subsequent period of 32 days ($r^2 = 0.74$). By contrast, the latter, *i.e.* water extraction during a period corresponding to grain filling (between 24 and 56 days after flowering) was positively related to pod yield ($r^2 = 0.36$). TE was positively correlated with pod weight ($r^2 = 0.30$) under drought condition. Our data showed that under the intermittent drought regime, TE and water extraction from the soil profile during a period corresponding to pod filling appeared to be most important traits.

Special Project Funding:
TLI

<div align="right">Vincent Vadez, P Ratnakumar, L Krishnamurthy and SN Nigam</div>

Activity 6.2.1.2 GN Marker-assisted breeding for drought tolerance in groundnut

Milestone Initial QTL map of component traits of drought tolerance (TE) developed using available populations 2009

Achievement of Output Target:
100%

Participating Countries:
Malawi, Tanzania, Senegal, Niger, Mali, India

Participating Partners:
NARS from above courtiers

Progress/Results:
Phenotyping for TE: The population TAG24 x ICGV86031 had been phenotyped in 2004 and 2005, although the range of variation between RIL was limited then, and this was attributed to the fact that the phenotyping had been performed in outdoors conditions under high VPD conditions, whereas the parental lines had been selected under glasshouse conditions and therefore low VPD conditions. This RIL has been re-phenotyped as an attempt to obtain larger phenotypic contrast for TE, by phenoyping under conditions of higher VPD, which were hypothesized to widen phenotypic contrast. As expected, a larger variation was obtained for TE (2.8-5.2 g DW kg^{-1} water) than in previous years when the population was phenotyped under low VPD. Seeds of that population were sent to Senegal, Malawi and Tanzania for field and TE assessment there. RIL ICGS76 x CSMG84-1 was phenotyped for TE (range 1.0-3.0 g DW kg^{-1} water).

Field evaluation of populations: The RIL population ICGS44 x ICGS76 (476 RIL progenies) was tested in the field in India in 2009 under both fully irrigated conditions and intermittent stress, following the same field protocol explained above.

The RIL population TAG24 x ICGV86031 was tested in Malawi in two locations (Kandiani and Kasinthula) under both fully irrigated conditions and intermittent stress, following the standard protocol across locations, and using a late planting to avoid the bulk of rains. The trial were visited and looked good. Trials have been harvested and data are still being curated. Seeds of that trial have been transferred to ICRISAT-Niger for testing in the field, a trial that is currently taking place (August sowing). The Senegal trial is on-going (late planting in the rainy season 2009).

Genotyping of population: The table below reports the number of polymorphic markers identified in each population.

S.No	Parental genotypes	No. of Markers screened	No. of Polymorphic markers	No of polymorphic loci in pop	No. of mapped loci	Population size
1	ICGV 86031 × TAG 24	3213	202	150	135	318
2	ICGS 44 × ICGS 76	3070	83	46	41	476
3	ICGS 76 × CSMG 84-1	2652	119	40	26	276

202 polymorphic markers were screened in RIL of ICGV86031xTAG24 and 165 loci mapped. 83 polymorphic markers were screened in RIL ICGS44 x ICGS76 and 63 loci mapped. 119 polymorphic markers were screened in RIL ICGS76 x CSMG84-1 and 84 loci mapped. 59 QTL, most with small effect, identified for several drought related traits, including TE.

Genetic analysis and QTL mapping: The mapping population TAG 24 × ICGV 86031 that segregates for drought component traits has been phenotyped for transpiration (T), transpiration efficiency (TE) in the summer of 2004, 2005 and in the rainy season 2008. Phenotyping for specific leaf (SLA) and SPAD chlorophyll meter readings (SCMR) was also done during summer 2004 and 2005. The phenotyping data along with genotyping data was used for composite interval mapping (CIM) of above mentioned traits with QTL Cartographer V. 2.5. Number of QTLs for drought component traits was obtained but majority of them were minor effect QTLs (Table 6.7). QTL analysis of T and TE showed 9 and 6 QTLs respectively across the three seasons with phenotypic variation ranging from 5.63- 10.86 for T and 5.99 - 9.00 for TE. In case of SLA 14 QTLs were identified across two seasons with phenotypic variation ranging from 3.50- 17.60. Similarly the data on SCMR yielded 16 QTLs with phenotypic variation ranging from 2.90- 11.0 across two seasons.

Table 7: QTLs for drought component traits identified by composite interval mapping (CIM).

Mapping population	Trait	No. of seasons	No. of QTLs	Phenotypic variation (r^2,%)
TAG 24 × ICGV 86031	Transpiration (T)	3	9	5.63 - 10.86
	Transpiration efficiency (TE)	3	6	5.99 - 9.00
	Specific leaf area (SLA)	2	14	3.50 - 17.60
	SPAD chlorophyll meter readings (SCMR)	2	6	
	SPAD at stage of harvest	2	10	2.90 - 11.0
ICGS 76 × CSMG 84-1	Transpiration (T)	1	1	12.37
	Transpiration efficiency (TE)	1	6	5.21 - 7.22

The results from the physiological analysis of the phenotypic data indicate that: (i) TE is likely a highly multigenic trait, explained by a number of physiological processes, some of which having antagonistic effects. Therefore, mapping of such traits might be more relevant than mapping the resulting trait; (ii) new genetic populations are needed that have a higher level of polymorphism. The available pool of SSR markers now available should normally suffice to develop populations with marker coverage satisfying breeding needs (> 1 marker/10 cM); (iii) the phenotypic contrast of the parents of the populations developed for TE is much lower than the range of phenotypic contrast for TE found in the reference collection, something that also stresses on the need to develop new populations.

Vincent Vadez, RK Varshney, P Ratnakumar, K Ravi,
SN Nigam, R Aruna, and D Hoisington

Milestone Range of variations for root traits assessed in groundnut germplasm, mapping populations initiated and potential for breeding for root traits assessed 2009

We no longer look at roots but make a comprehensive assessment of yield related traits, including water extraction from roots. So, no RIL is being developed for roots.

Vincent Vadez

Activity 6.2.1.3 GN Develop groundnut transgenic events for enhanced tolerance to drought

Milestone 1 – 2 transgenic DREB events of groundnut available for introgression into locally adapted germplasm in India 2010

Achievement of Output Target:
75 %
The introgression work of DREB1A from two promising events is currently on-going. As such there is no detailed report to provide. The developed materials will be screened initially in lysimeters to test the effect of the introgression on the yield under intermittent drought of the introgressed lines (ICGV86031).

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Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
We have reported above some promising data on a few DREB1A transgenic events. These would be good candidate for introgression into popular varieties. This work is currently ongoing.

Special Project Funding:
Nil

Output target 2011 6.2.2 GN 15-20 introgressed transgenic lines of groundnut evaluated under water-limiting conditions

Achievement of Output Target:
75 %
The BC3 populations are being advanced for phenotyping

Participating Countries:
Nil

Participating Partners:
Nil

Progress/Results:
The BC3 populations generated so far are being advanced to further generations for subsequent phenotyping under strip trials. The expression studies are underway for DREB1A protein for generating the preliminary biosafety data for conducting the BRL 1 trials with the selected events in near future.
Special Project Funding:
Nil

KK Sharma, Pooja Bhatnagar-Mathur and SN Nigam

Activity 6.2.1.4 GN Marker-assisted breeding for salinity tolerance in groundnut

Milestone: Mechanisms responsible for differences in salinity tolerance in groundnut identified and mapping population development initiated 2009

Achievement of Output Target:
100%
We have had 3 trials repeated using the minicore collection and are confident that both reproduction and pod filling are critical traits affected by salinity in peanut

Participating Countries:
India

Participating Partners:
None

Progress/Results**:**
A total of 275 accessions of groundnut were screened across two different seasons for their response to yield under saline condition. Salinity appeared to affect less the number of pods, which decreased only about 20-40% under salinity, than the pod weight which decreased more than 50%. This suggested that salinity affected seed development relatively more than pod formation, in agreement with a lower maturity index and a delay in the days to flower under saline stress. The number of days to flower had a significant although weak relationship with pod weight under salinity (R^2= 0.20 and 0.33 in 2 different trials), showing that genotype duration had little influence on plant tolerance to salinity stress. Shoot dry weight was negatively correlated with the total shoot Na^+ %, but there was no relationship between pod dry weight and shoot Na^+ %. This showed that, as in chickpea, the Na accumulation in shoot, although different between genotypes, did not appear to have any particular influence on the plant tolerance based on seed yield.

Special Project Funding:
Former Water and Food CP – No funding now

V Vadez and SN Nigam

Milestone QTLs for salinity tolerance identified 2011

Achievement of Output Target:
25%
After the end of the Water and Food CP project, which was funding salinity tolerance screening in groundnut and pigeonpea, the activities related to salinity stress have decreased in intensity. The selection of suitable parents (both phenotypically and genotypically) has been done and initial crossing work has been performed. However, unless special project funding is identified, there is no plan to expand in that area in the coming year, mostly based on current funding and time.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
During the 2009 rainy season, F₁ populations of 9 crosses were advanced and back crosses were made.

SN Nigam

Chickpea

Output target 6.2.1 CP Biotechnological strategies developed for improving drought avoidance root traits and salinity tolerance in chickpea

Activity 6.2.1.1 CP Marker-assisted breeding for drought tolerance in chickpea

Milestone Assessment of water uptake and related kinetics in contrasting genotypes for root traits studied using a lysimetric system 2009

Achievement of Output Target:
50%
We still need to repeat the trial in 2010-11. the trial carried out in 2008-09 failed and we had the first data set this year only (chickpea has a short cropping season possible)

Participating Countries:
India

Participating Partners:
Kenya, Tanzania, Ethiopia

Progress/Results:
The experiment carried out in 2008-09 failed because of strong wilt infection. A similar experiment is currently in progress, involving 20 genotypes contrasting for pod yield in the field, based on 3 years of data. A particular focus of this current work is to assess the kinetics of water extraction and the success of reproduction and pod filling, by regularly measuring water extraction and dating each flower produced.

V Vadez and Mainassara Zaman

Output target 2010 6.2.1 CP MABC derived drought tolerant lines available from 2-3 locally adapted cultivars

Achievement of Output Target:
80%
The development of introgression lines with a root QTL from donor parent ICC4958 and ICC8261 is on-going and almost completed.

Countries Involved:
India, Ethiopia, Tanzania

Partners Involved:
NARS of India, Ethiopia and Tanzania

Progress/Results
With an aim of introgressing root traits for drought tolerance in farmer preferred cultivars through MABC, two genotypes ICC 8261 and ICC 4958 were chosen as donor parents based on their high performance for root length density and drought tolerance. Following three genotypes have been chosen as recurrent parent: (a) ICCV 92318 (kabuli type), released as Chefe in Ethiopia and as Hawata in Sudan and performing well in Kenya and Tanzania; (b) ICCV 92311 (kabuli type), released as KAK 2 in India and performing well in Kenya and Tanzania; and (c) ICCV 93954 (desi type), released as JG 11 in India and expected to perform well in SSA. Three crosses (ICCV 92318 × ICC 8261; ICCV 92311 × ICC 8261; ICCV 93954 × ICC 4958) were made during crop season 2006/07. F1s from these crosses were grown in greenhouse during the off-season in 2007 and were backcrossed to the recurrent parent: (a) ICCV 92318 × (ICCV 92318 × ICC 8261), (b) ICCV 92311 × (ICCV 92311 × ICC 8261); (c) ICCV 93954 × (ICCV 93954 × ICC 4958). For initiating foreground selection, root trait phenotyping data and SSR genotyping data obtained from intraspecific mapping population ICC 4958 × ICC 1882, a hotspot harboring several root trait QTLs with 34 - 36% phenotypic variation have been identified on LG 5, with flanking markers TAA 170 and ICCM 0249. Genomic region bracketed by SSR markers (TAA 170 and ICCM 0249) has been used to select heterozygote plants carrying drought resistance gene for foreground selection, while 8 AFLP primer combinations were used to select the plants with higher genome recovery of the recurrent parent for background selection. Two cycles of marker-assisted backcrossing was performed to generate BC3F1s. Plants heterozygous for all the 3 markers with over 85% genome of recurrent parent (n=10+7+7 = 25) were identified in BC3F1 and selfed for generating BC₃F₂. The BC3F2 plants were subjected to foreground selection for selection of plants homozygous for allele from the donor parent (ICC 4958 or ICC 8261) using TAA 170 and ICCM 0249 markers and 57 plants across all the 3 populations (47+8+2) were identified to be homozygous for allele from donor parent. These plants will be used to develop progenies which will then be evaluated at multilocations for yield under drought conditions.

PM Gaur, RK Varshney, C Siva Kumar,
S Tripathi, V Vadez and L Krishnamurthy

Activity 6.2.1.2 CP Mapping and marker-assisted breeding for salinity tolerance in chickpea

Milestone Mechanisms of tolerance to salinity characterized 2009

Achievement of Output Target:
100%
We have a number of paper in progress to report the fact that reproduction is the most important trait affected by salinity in chickpea. We have tested and confirmed the validity of that hypothesis using different types of materials

Participating Countries:
India, Australia

Participating Partners:
CLIMA, UWA, PAU

Progress/Results:
We have assessed the sensitivity of reproductive stages to salinity. We have carried out 3 trials in 3 consecutive years using 3, 6 and 5 pairs of tolerant/sensitive lines. Across experiments we consistently find that tolerant lines were those capable of producing more number of flowers under saline stress. We also found that the percentage of pods filled with seeds was higher in tolerant lines, fully in line with previous year's data. Data are currently being summarized for publication.

Special Project Funding:
ARC-linkage grant

<div align="right">Vincent Vadez and L Krishnamurthy</div>

Milestone Contrasting materials (varieties, breeding lines, germplasm) for salinity tolerance assessed under field conditions 2010

Achievement of Output Target:
50%
Thee partners received seeds. One trial failed (HAU), one trial was completed successfully (PAU) and we have not heard from the third one (UAS Dharwad)

Participating Countries:
India

Participating Partners:
HAU, PAU, UAS-Dharwad

Progress/Results:
The pot screening method was transferred from ICRISAT to PAU. The experiment evaluated 50 genotypes, sown into 11 kg pots outdoors on 5 November, 2008. Two saline treatments were imposed (40 and 60 mM NaCl), but disease issues and watering techniques were not optimal, so the trial will be repeated in 2009/10. The field trial at Bhatinda station with 20 genotypes, two treatments (non saline field and a salt-affected soil with poor quality irrigation water) and 3 replicates, was successful. Variation in salinity tolerance was confirmed. As examples, for parents of RILs: (i) ICC1431 had only a 26% decrease in yield, whereas ICC6263 suffered a 58% yield decrease, (ii) JG11 was reduced only 11% whereas ICCV10 was reduced 33%. These data from North India confirm the differences in tolerance as identified in the different climate at ICRISAT in South India, and demonstrate field performance of the lines.

Evaluate the salinity tolerance of 20 lines of chickpea at 3 saline field sites in India differing in soil type and temperature during the growing season. Experiments were conducted at 3 locations: PAU Bathinda (described above), CCHAU Hisar in northern India, and UAS Gangavathy (Karnataka) in peninsular India. At Hisar plant deaths caused by salinity increased as the season progressed, so that density was reduced by more than 70% in all the genotypes, so that plot yields were low. Nevertheless, genotypes identified as tolerant at ICRISAT (e.g. ICC 15868 and 1CC 7819) had yields comparable to the tolerant check CSG 8962 (around 201 kg/ha), but a local check (HC3) had highest yield (502 kg/ha). Variation amongst replicates was large, indicating variation in salinity levels of the plots. Data from the experiment at Gangavathy are still to be finalized.

Special Project Funding:
ARC-linkage grant

<div align="right">V Vadez, L Krishnamurthy and PM Gaur</div>

Output target 2011 6.2.1 CP QTLs for salinity tolerance in chickpea identified

Achievement of Output Target:
50%
We have identified salinity tolerance QTL in one RIL population. There are two additional RIL population developed for that same purpose under way. One has just been phenotyped (2009-10) and the other one will be phenotyped in 2010-11. QTL identification will be considered complete when done in at least 2 populations.

Participating Countries:
India and Australia

Participating Partners:
PAU, UWA, CLIMA, COGGO

Progress/Results:

As mentioned in the earlier report, in order to identify and map QTLs for salinity tolerance in chickpea, genotyping data have been generated for 204 markers on the 126 RILs of mapping population ICCV 2 × JG 62. Phenotyping of the mapping population ICCV 2 × JG 62 for various salinity tolerance traits for instance days to flower, total shoot weight, total seed weight and harvest index , have been done during 2007-08. The segregation data are being used to calculate the map distance. As a result a genetic linkage map with 122 loci was constructed (Fig. 6.3). The linkage mapped spanned 318.2 cM, with average inter marker distance of 2.6 cM. Genotyping and phenotyping data will be analyzed to identify QTLs for salinity tolerance.
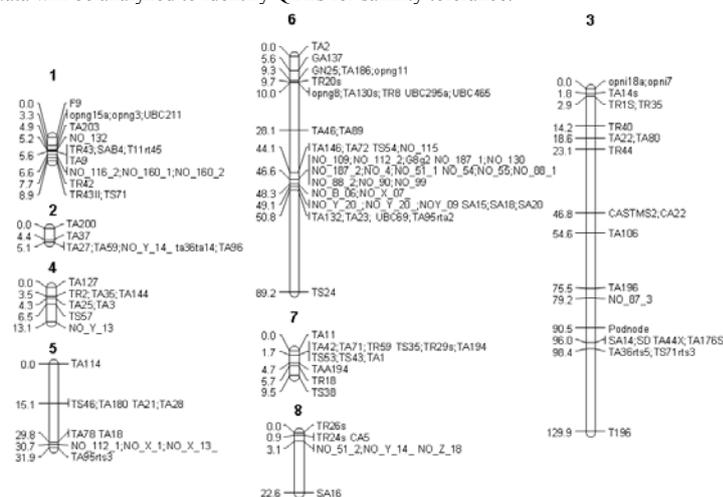
Figure 6.3: A linkage map of chickpea developed based on ICCV 2 × JG 62 RILs, consisting of 122 loci mapped onto 8 linkage groups.

RK Varshney, T Mahender, V Vadez, L Krishnamurthy and PM Gaur

Milestone Introgression of QTLs for salinity tolerance initiated in farmer-preferred varieties 2011

Achievement of Output Target:
0%
The introgression work will start after validation of salinity tolerance QTL

Participating Countries:
None

Participating Partners:
None

Progress/Results:
This activity will be initiated after identification and validation of QTLs for salinity tolerance.

PM Gaur

Activity 6.2.1.3 CP Develop and evaluate chickpea transgenic events for enhanced tolerance to drought stress

Output target 2011 6.2.1 CP Transgenic DREB/P5CSF events available for introgression into locally adapted genotypes

Achievement of Output Target:
50 %
Six promising DREB1A transgenic events (T6) were identified. A strip trial for event selection under net house in field will be carried out in Jan 2010.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
The results obtained with the selected events of DREB1A chickpea transgenics were confirmed during. Over, 18 independently transformed plants of *rd29A:DREB1A* (2nd phase*)* were analyzed at molecular and physiological levels. Based on the previous findings only 4 promising lines were advanced to T6 generation. The selected events were confirmed for the presence and expression of the transgenes by using PCR,

RT-PCR, semi-quantitative RT-PCR and their inheritance was studied. These events were subjected to physiological characterization for drought tolerance based on the yield parameters, harvest index and transpiration efficiency. This was done by screening the transgenics in dry down experiments in lysimeters in P2 glass house facility. Preliminary yield trials of the selected transgenic events conducted in the controlled lysimetric conditions where the effect of drought on the various potential component traits of yield architecture such as Transpiration (T), Transpiration Efficiency (TE) and root profile were addressed comprehensively during June-September 2009.

The experimental results showed some significant variation in pod data. However, information on the yield was not obtained since the experiment was terminated before the completion of chickpea life cycle, another experiment to study the yield parameters for the 4 events has been initiated in Oct 2009. These two experiments will help proving insights about the performance of these transgenics under drought stress. Based on these results a strip trial for event selection will be conducted to access the transpiration efficiency and yield for the same events. The remaining events are being advanced to further generations for seed multiplication for future evaluations. Besides, new marker-free transgenic events, are being developed using pPZP200>*RD29A: DREB1A* plasmid. Over 20 transgenic events are currently being produced and 15 events have been transferred to greenhouse and are undergoing preliminary molecular characterization by PCR, RT PCR, and Inverse-PCR. These events will be advanced for further generations and will be screened for drought tolerance by lysimetric experiments in P2 glass house facility. An application to carry out strip trials under field with the selected events was made to IBSC/RCGM and has in principle been approved, following receipt of which the strip trials for event selection under net house in field will be carried out in Jan 2010.

Special Project Funding:
ISCB

<div align="right">KK Sharma, Pooja Bhatnagar, V Vadez and PM Gaur</div>

Activity (New) 6.2.1.4 CP Mapping and marker-assisted breeding for heat tolerance in chickpea

Milestone Identification of heat tolerant genotypes for developing mapping and breeding populations 2009

Achievement of Output Target:
100 %

Participating Countries:
India

Participating Partners:
Indian Institute of Pulses Research, Kanpur, Punjab University, Chandigarh, Jawaharlal Nehru Agricultural University, Jabalpur, Madhya Pradesh and Acharya NG Ranga Agricultural University, RARS-Nandyal, Andhra Pradesh

Progress/Results:
New sources of heat tolerance were identified by evaluating germplasm/breeding lines in late sown conditions that expose the crop to high temperatures at reproductive phase. A screening of 180 genotypes at Patancheru (southern India) during 2007/08 and 115 genotypes at Patancheru and Kanpur (northern India) during 2008/09 revealed a wide variation for heat tolerance in chickpea. The genotypes that showed high heat tolerance and gave higher yields than the best known heat tolerant line ICCV 92944 over two years at Patancheru included ICCV 07104, ICCV 07105, ICCV 07110 and ICCV 07115. The genotypes that showed high levels of heat tolerance both at Kanpur and Patancheru included ICCV 07104, ICCV 07105 and IPC 2006-99. Efforts are being made to understand mechanisms and genetics of heat tolerance and develop simple and effective screening techniques. The newly identified heat tolerant lines are being used in breeding programs to develop high yielding, heat tolerant varieties with desired agronomic and seed traits.

Special Project Funding:
Government of India under TMOP.

<div align="right">PM Gaur, S Tripathi, CLL Gowda, N Mallikarjuna,
L Krishnamurthy, V Vadez and R Varshney</div>

Pigeonpea

Output target 6.2.1 PP Improved pigeonpea for salinity tolerance using biotechnology

Activity 6.2.1.2 PP Develop intra- and inter-specific mapping population of pigeonpea between contrasting materials for salinity tolerance

Milestone At least two mapping populations developed to map QTLs for salinity tolerance in pigeonpea 2010

This activity will be initiated after conferring levels of salinity tolerance.

Output 6.3: Annually knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification, breeding improved germplasm and management strategies (against mycotoxin contamination) of mandate crops and associated capacity building made available to partners internationally

Output target 6.3.1 FORT High yielding and micronutrient dense hybrids/improved populations/varieties of sorghum and promising transgenic events of groundnut and pigeonpea with high beta-carotene content available for testing in national trials

Activity 6.3.1.1 FORT Develop groundnut transgenic events for enhanced production of beta-carotene

Output target 2010 6.3.1 FORT At least 8 groundnut candidate psy1 events with beta- carotene selected for contained field trial

Achievement of Output Target:
50 %
Seven promising T1 events with 10-fold increase carotenoids levels were identified and advanced to T2. Further study is underway.

Progress/Results:
Seventy two events out of 90 primary transgenic events carrying *oleo: psy* genes have been advanced to next generation. Molecular analysis of the transgenic events using PCR with gene-specific primers revealed the integration and presence of the transgene. Transgene expression in the developing pods of groundnut was observed by RT- PCR analysis. The inheritance pattern was studied in the transgenic events which confirmed Mendelian segregation in most of the transgenic events. Southern analysis was carried out with selected events and copy number ranged from one to three copies of the transgene. Molecular and biochemical data showed the stability of gene in advanced generations.

For carotenoid profiling of groundnut seeds, different protocols that are available for extraction of carotenoids in various crops were tried. Recovery percentage was calculated using spiked ß- carotene, where 20 -65% recovery was obtained using these protocols. Since efficient recovery of beta carotene was a major bottleneck so far due to higher oil content in the groundnut seeds. Efforts were made to optimize protocol for efficient recovery of ß- carotene in transgenic events where the ß- carotene was targeted to oil bodies. A modified protocol has been developed taking into consideration the ratio of polar to non-polar solvents and saponification conditions which resulted in >90 % recovery of ß- carotene in our transgenic events. Using this protocol extraction and quantification of the total carotenoids and ß-carotene in T_1 transgenic seeds was carried out for screening the events. The level of total carotenoids was 10 to 12-fold higher in transgenic events as compared to the untransformed controls. On the basis of total carotenoids and HPLC data, 7 events were selected and advanced to T_2 generation. Beta carotene levels in these transgenic events ranged from 0.01-0.32 ug /gm in T1 seeds which is a 10 fold increase than the control plants. In T_2 seeds beta carotene range was 0.04-1.54 µg/gm. However, other associated carotenoids such as Lutein, ß-Cryptoxanthin have been found to be increased by 10- 15 fold in transgenics as compared to control. (ß-Cryptoxanthin ranged between 0.22-9.65 µg/gm).

Besides, 30 primary events using pCAMBIA:oleo:φnptII:psy and 42 using pPZP 200:oleosin:psy have been produced to generate clean marker free system. Out of them, 40 transformants were advanced to T_1 generation on the basis of molecular and biochemical data. The total carotenoid level in these transgenic events was 6-fold higher than the untransformed control. ß-carotene levels of 0.03-1.21 µg/gm were detected in T_1 seeds of marker free transgenics. On the basis of HPLC profiling total 19 events have been selected and advanced to T_2 generation. Integration and stability of gene was confirmed by molecular and biochemical analysis in further generation. In T2 seeds on an average 0.03-0.74µg/ gm of beta carotene were detected. 8 events (4 from marker free and 4 from construct containing selectable marker were selected on basis of beta carotene quantification and advanced to T_3 generation. The individual carotenoid profiling of these events is underway.

An intriguing observation was that the transgenics had much higher lutein content amongst the individual carotenoids. Since, *ß-lycopene cyclase* (*BLYC*) is the key enzyme involved in ß-carotene biosynthetic pathway (where lutein to γ carotene and γ-carotene to ß-carotene conversions take place), we assume that over expression of *BLYC* may result in much higher accumulation of ß-carotene. On the basis of sequence information available we have cloned the Ta*BLYC* gene from tomato in pGEMT-Easy vector and got it sequenced. The Ta*BLYC* gene was sub cloned in to binary vector Pzp200.oleo.psy and have been using for pyramiding of these two genes to meet the target levels of provitamin A. Over 20 newer marker free transgenic groundnut plants carrying maize *psy1* and tamato *BLYC* genes were developed and molecular characterization is going on which will be followed by carotenoid profiling of these events.

KK Sharma, Pooja Bhatnagar-Mathur and SN Nigam

Output target 2011 6.3.1 FORT Bioavailability studies with 2-3 selected beta-carotene transgenic events carried out

Achievement of Output Target:
30 %
The transgenic events are being screened for the beta carotene content and will be later studied for bioavailability studies.

Progress/Results:
The transgenic events are being screened for the beta carotene content. These events will be advanced to further generations for gene stability and expression before being used for bioavailability studies.

KK Sharma and Pooja Bhatnagar-Mathur

Milestone One or two transgenic events of groundnut with high beta-carotene content used for introgression into locally adapted genotypes and the progeny characterized and evaluated 2011

Achievement of Output Target:
30%
The transgenic events will be introgressed in local cultivars after conclusion of gene stability and expression studies.

Participating Partners:
None

Progress/Results:
The transgenic events are being screened for the beta carotene content and subsequently will be advanced to further generations for gene stability and expression before being used for introgression studies.

Special Project Funding:
None

KK Sharma and Pooja Bhatnagar-Mathur

Activity 6.3.1.2 FORT Develop pigeonpea transgenic events for enhanced production to beta-carotenes.

Milestone 5-7 introgressed transgenic lines of pigeonpea with enhanced beta-carotene content evaluated and development of commercialization package initiated 2011

Achievement of Output Target:
25%
The transgenic events will be introgressed in local cultivars after conclusion of gene stability and expression studies.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
The transgenic events are being screened for the beta carotene content and subsequently will be advanced to further generations for gene stability and expression before being used for introgression studies.
Special Project Funding:
None

KK Sharma and Pooja Bhatnagar-Mathur

Activity 6.3.1.3 FORT Selecting sorghum lines for high grain Fe and Zn contents

Milestone Three varieties with high grain Fe (>40ppm) and Zn (>30 ppm) contents identified 2010

Achievement of Output Target:
50%
Varieties and R lines with high contents of Fe (up to 47 ppm) and Zn (up to 30 ppm) have been identified for further evaluation

Participating Countries:
India

Participating Partners:
Partners of Sorghum Hybrid Research Consortium and NARS

Progress/Results:
Fifty ICRISAT-bred R-lines were evaluated for grain Fe and Zn contents along with the control PVK801 in the 2008 postrainy season. The grain analysis for Fe and Zn contents was done at Waite Laboratories, Australia. They showed an average Fe content of 32 ppm and average Zn content of 21 ppm with a range of 24 to 47 ppm for Fe and 17 to 30 ppm for Zn. Thirty three R-lines showed Fe contents above 30 ppm and two R- lines ICSR 89035 (Fe 47 ppm and Zn 30 ppm) and ICSR 59 (38 ppm Fe and 25 ppm Zn) showed significantly higher grain Fe and Zn contents than the control PVK 801 (37 ppm grain Fe and 20 ppm Zn).

More than 200 BC_2s made between grain micronutrients (Fe and Zn)-dense germplasm lines and high yielding breeding lines were evaluated in 2009 rainy season and selected 12 progenies with R- reaction and are in evaluation in postrainy season for R-line/variety development.

Special Project Funding:
Harvest plus

BVS Reddy and A Ashok Kumar

Output target 6.3.2 DTOX Transgenic groundnut with enhanced resistance to *Aspergillus flavus* and aflatoxin production identified and available for introgression into regionally adapted germplasm

Activity 6.3.2.1 DTOX Develop and evaluate groundnut transgenic for enhanced resistance to *Aspergillus flavus*

Output target 2010 6.3.2 DTOX Five promising transgenic events of groundnut with PNLOX13S gene for *A. flavus* resistance identified

Achievement of Output Target:
50 %
Molecular characterization of transgenic events has been carried out. Work is underway to develop groundnut and tobacco transgenic plants using these two new constructs.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Molecular characterization of 20 previously developed transgenic events carrying 35S: PN LOX13S has been carried out. Some of these transgenic events have been advanced to T2 generation for seed multiplication and inheritance studies. The phenotyping of these transgenic events in greenhouse conditions have been planned in near future. Since, elongation of these events was a major bottleneck, efforts were made to isolate novel seed specific promoters from groundnut (GSSP) and chickpea (CPLP) to target the expression of the lipoxynase gene at seed level since seed is the ultimate target for *A. flavus* infection. The efficiency of both the promoters has been confirmed through promoter binding studies using electro mobility shift assay (EMSA) and by histochemical GUS expression in *Arabidopsis*. Constructs were made using both these promoters to drive the peanut lipoxygenase gene (*PnLOX3)*. Work is underway to develop groundnut and tobacco transgenic plants using these two new constructs (pPZP:GSSP:*PnLOX3* & pPZP:CPLP:*PnLOX3*).

Special Project Funding:
None

KK Sharma, Pooja Bhatnagar-Mathur and SN Nigam

Output target 6.3.3 DTOX Simple and cost-effect test for the estimation of mycotoxins (Aflatoxins, Fumonisins and Ochratoxin-A) in crops and commodities, and aflatoxin-adducts in human serum developed and validated

Activity 6.3.3.1 DTOX Develop simple and cost-effective assays for the detection of mycotoxins in crops and commodities

Milestone Multiplex filter paper immunoassay developed for the rapid estimation of aflatoxins and fumonisins 2009
No activities during 2009

Output target 6.3.4 DTOX Aflatoxin resistant/tolerant groundnut genotypes identified

Activity 6.3.4.1 DTOX Evaluate groundnut varieties for resistance to *Aspergillus flavus* and aflatoxin production by *in vitro* inoculation studies and on-station testing in sick fields
Milestone Preliminary, advanced and elite foliar disease resistant breeding lines evaluated for resistance A. flavus and aflatoxin production under artificial inoculation conditions in the field 2009

Achievement of Output Target:
100%

Participating Countries:
India

Participating Partners:
ICRISAT, groundnut breeding

Progress/Results:
A total of one hundred two advanced breeding lines (including checks) were evaluated during 2008-09 post rainy season for their resistance to *A. flavus* seed infection and aflatoxins contamination. Based on category of the materials these lines were divided in to four trials namely EAFRGVT (elite *A. flavus* resistant groundnut varietal trial), PAFRGVT (preliminary *A. flavus* resistant groundnut varietal trial), ECGVT-SB (elite confectionery groundnut varietal trial Spanish bunch), ECGVT-VB (elite confectionery groundnut varietal trial Virginia bunch) and tested in six replications. The trials were laid out in the field using lattice or RBD. All the test materials were planted in the newly developed AF sick plot in RP 14 field, *A. flavus* inoculum multiplied on sorghum or maize seed was applied in the soil near to the groundnut plants. The inoculum was applied 4-5 times at about 10 days interval during the crop growth period and end of season drought was imposed 30 days before harvest to facilitate the seed infection. Pod from each plot were collected separately, shelled manually and kernel sub-samples were taken for *A. flavus* seed infection using blotter plate method and aflatoxin contamination by indirect competitive ELISA method. *A. flavus* infection and aflatoxins contamination in individual samples in test lines ranged from 0 to 31% and 0 to 3197 µg/kg respectively. Three EAFRGVT lines (ICGV 07156, 07171 and 07174), twelve PAFRGVT lines (ICGV 08002, 08006, 08009, 08014, 08016, 08030, 08035, 08038, 08039, 08041, 08043 and 08045), two ECGVT-SB lines (ICGV 06199 and 006201), four ECGVT-VB lines (ICGV 06216, 06220, 06227 and 07362) showed lower AF seed infection and aflatoxin contamination (<5 µg/kg).

Special Project Funding:
None

Varsha Wesley, SN Nigam and R Aruna

Output target 2011 6.3.4 DTOX Ten interspecific derivatives of groundnut evaluated for *A. flavus* resistance and promising lines identified

Achievement of Output Target:
50 %
Ten lines were selected which had less than 10% *A. flavus* infection and less than 10 ug/kg aflatoxin production. These lines will be screened again for *A. flavus* infection and aflatoxin production in 2010

Participating Countries:
None

Participating Partners:
None

Progress/Results

Screening of 100 lines of advanced generation interspecific derivatives of groundnut for *Aspergillus flavus* infection and aflatoxin production was carried out by growing the material in *A. flavus* sick plot generated and maintained by groundnut pathology group. Entries were grown in three replications using randomized block design. During germination and growth, field was irrigated and fertilized but no protection measures were taken. Plants were allowed to grow, flower and set seeds. Seeds were harvested as individual replications.

Seeds from each entry were subjected to artificial inoculation by *A. flavus* fungus and percent infection was calculated. All the entries were subjected to aflatoxin production by ELIZA technique standardized at ICRISAT. The results showed that one line did not have any fungal growth and colonization on the seeds and hence no aflatoxin was detected in the seeds. This line can be classified as resistant to *A. flavus*-aflatoxin complex. Lines with 10 ug/kg were selected as the samples for further study and use in the crossing program to transfer resistance to aflatoxin. Based on this criteria 24 lines were selected which had less than 10% *A. flavus* infection and less than 10 ug/kg aflatoxin production (Table 8).

Table 8. Advanced generation Interspecific derivatives screened for A.flavus-aflatoxin at ICRISAT in 2009.

Line no.	Derived from	Mean	
		A. flavus infection (%)	Aflatoxin (ug/kg)
1	*A. batizocoi* x *A. hypogaea*	8.0	0.9
2	*A. batizocoi* x *A. hypogaea*	3.0	1.9
3	*A. hypogaea* x *A. kempff-mercadoi*	8.1	1.0
4	*A. hypogaea* x *A. kempff-mercadoi*	32.0	0.0
5	*A. hypogaea* x *A. kempff-mercadoi*	5.6	1.4
6	*A. hypogaea* x *A. cardenasii*	5.0	0.0
7	*A. hypogaea* x *A. cardenasii*	0.0	0.0
8	*A. hypogaea* x *A. cardenasii*	7.4	0.0
9	*A. hypogaea* x *A. cardenasii*	6.0	0.0
10	*A. hypogaea* x *A. cardenasii*	6.7	4.1
11	*A. hypogaea* x *A. cardenasii*	8.7	1.8
12	*A. hypogaea* x *A. cardenasii*	10.0	2.4
13	*A. hypogaea* x *A. cardenasii*	6.6	1.5
14	*A. hypogaea* x *A. cardenasii*	5.0	0.5
15	*A. hypogaea* x *A. cardenasii*	7.1	6.3
16	*A. hypogaea* x *A. cardenasii*	2.0	1.5
17	*A. hypogaea* x *A. stenosperma*	4.0	1.5
18	*A. hypogaea* x *(A. correntina* x *A. diogoi)*	7.3	0.6
19	*A. hypogaea* x *(A. correntina* x *A. diogoi)*	8.3	1.2
20	*A. hypogaea* x *A. cardenasii*	9.0	1.0
21	*A. hypogaea* x *A. cardenasii*	5.4	0.0
22	*A. hypogaea* x *A. cardenasii*	8.0	0.7
23	*A. hypogaea* x *A. cardenasii*	4.0	0.0
24	*A. hypogaea* x *A. cardenasii*	NT	2.2
25	TMV2 (cultivated *A. hypogaea*) - Check	9.0	12.1

Due to the nature of *A. flavus*-aflatoxin complex, resistant lines will be screened again for *A. flavus* infection and aflatoxin production in 2010. In the meantime, six lines with less than 5 ug/kg aflatoxin production were used in the crossing program and crossed with elite cultivars ICGV 91114, ICGV 87846 and ICGS 76.

Since ICRISAT is generating synthetic groundnuts, crossing initiative was undertaken to cross two selected synthetic groundnuts with three cultivars of *A. hypogaea*. F_1 hybrid seeds were obtained, which will be grown in the glasshouse to generate BC_1 seeds/plants. Synthetic groundnuts will be screened in the *A. flavus*-aflatoxin sick plot in 2010. This is another mode of introgression of *A. flavus* resistance from wild *Arachis*.

Nalini Mallikarjuna and Groundnut pathology staff

Output target 6.3.5. IPM Effective and eco- friendly IPM technologies designed, evaluated and shared with the NARS/NGOs

Activity 6.3.5.1 IPM Develop and validate effective IPM technologies for crop production

Milestone Mass production techniques developed for biopesticides, and their stable formulations developed 2009

Achievement of Output Target:
100%

Progress/Results:
Production of NPV: Two talc based powder formulations of *Helicoverpa* NPV have been developed and their bio-efficacy evaluated under laboratory and field conditions. These powder formulations after five months of storage under laboratory conditions showed 84-94% mortality compared to 100% of fresh virus. Evaluation of these formulations under field conditions in chickpea revealed encouraging results with 94% reduction in larval population (control has 0.85 larva plant[-1]) which was on par with chemical (monocrotophos) at one week after application. After 13 days of application, the larval population in NPV applied plots started increasing with 0.65 larvae plant[-1] compared to 0.3 in chemically treated where as control had 1.0 larva plant[-1], indicating the low level of persistence compared to chemical (monocrotophos).

<div align="right">GV Ranga Rao</div>

Mass production techniques for entomopathogenic fungi such as *Metarhizium anisopliae* and bacteria such as *Bacillus subtilus* (BCB 19) are developed: Mass multiplication of *M. anisopliae* was standardized using 4% potato flakes broth on a sterilized steel tray (38 x 28 cm). Once the fungi was grown, conidial layer's were collected, homogenized with tissuemizer, centrifuged at 3000*g* for 10min and finally collected as pellet. An average of $5x10^{12}$ conidia from each tray could be harvested and with these conidia different types of formulations can be prepared *viz.*, powder, tablet/mini biscuit and liquid. Mass multiplication of *Bacillus subtilus* (BCB19) was also standardized using 4% potato flakes broth on a steel tray (as described earlier for *M. anisopliae*) and shared with members of BRC. In order to prepare the powder formulation, 1ml of spore mass was mixed with 1ml of sterilised glycerol and 20g of gamma irradiated sugar powder followed by kneading the powder well to get the friable powder formulation. Each gram of powder contains around $3.0x10^9$ bacterial spores.

<div align="right">S Gopalakrishnan</div>

Milestone IPM options tested and validated on-station and on-farm, and disseminated to the farmers through NARS and NGOs 2011

Achievement of Output Target:
50%
Studies during 2009 brought out the positive effects of inorganic dusts on pulse bruchids and the potential role of actinomycetes and botanicals in the management of Helicoverpa. Further studies are in progress to make use of these options in targeting legume pests.

Progress/Results:
Evaluation of eight organic dusts against the pulse bruchid in chickpea revealed the superiority of talc dust in minimizing the oviposition as well as damage. When seeds were treated with talc dust (1: 20 by volume) there was significant reduction in oviposition (1%) compared to 34% oviposition in control and 0% in chemical treated seed (Malathion 5% dust). Though the other plant products (neem leaf powder, neem fruit powder, custard apple leaf powder, eucalyptus leaf powder and wood Ash) have shown superiority over control but inferior to talc powders and chemical. Low oviposition in talc treatment also resulted in lower damage (0-3%) compared to 12% in control and 2% in chemical at 40 days after adult release which reflected it's potential as seed protectant against bruchid management in pulses.

<div align="right">GV Ranga Rao</div>

Identification of the potential entomopathogenic bacteria and actinomycete isolates by molecular means (16s ribosomal DNA analysis): A total of 3 potential biocontrol actinomycete isolates, (CAI 21 [*Streptomyces albus*], CAI 26 [*S. champavatii*] and MMA 32 [*S. roseoviolaeus*; which were antagonistic against *Fusarium oxysporum* F. sp. *ciceri* and *Macrophomina phaseolina*) were evaluated for their entomopathogenic traits on *Helicoverpa armigera*. The antagonistic isolates were partitioned against ethyl acetate and the resultant organic and aqueous phase were evaluated for their killing effect on 3-4 days old *Helicoverpa* larvae. Among the three actinomycetes evaluated, organic phase of the isolate MMA 32 showed 67-93% mortality in 3 days whereas in the control the mortality was only between 27% and 33%. This result was highly trustable as the whole experiment was repeated four times and each time 15 replications were made, so it can be firmly concluded that the isolate MMA 32 contains some secondary metabolites that are capable of killing *Helicoverpa*. Further, secondary metabolites present in the organic phase of MMA 32 may be separated and used as bio-pesticide.

Natural plant products that kills *Helicoverpa* and *Spodoptera* be evaluated and checked for their compatibility with entomopathogenic micro-organisms: Seven herbal vermicompost was used for this study, viz. *Anona, Datura, Pongamia, Parthinium, Gliricedia*, Neem and *Jatropha*. Biowash of these vermicomposts were collected ("crude"), partially purified (by C18 solid phase extraction cartridge), to get adsorbed and non-adsorbed fractions, and were studied for their bio-efficacy. In the case of crude bio-washes, maximum mortality was observed in *Anona* (38%) followed by *Pongamia* (38%), *Gliricedia* (37%) and Neem (37%) whereas all the seven crude bio-washes showed reduction in the weight as compared to control, ranging 24% (*Parthinium*) to 60% (*Anona*). Adsorbed fraction exhibited a mortality range between 42% (*Datura*) to 82% (*Jatropha*) whereas all the 7 bio-washes showed reduction in weight compared to control with the max weight reduction was recorded in *Jatropha* (97%) followed by *Parthinium* (89%), Neem (84%), *Pongamia* (73%), *Datura* (71%), *Gliricedia* (70%) and *Anona* (65%). In the case of non-adsorbed fraction, mortality was ranged between 13% (Neem) to 53% (*Pongamia*) and weight reduction (%) of the larvae was found in all 7 bio-washes compared to control with the max was found in *Datura*

(76%) while min was found in Neem (69%). Hence it can be concluded that among the 7 bio-washes studied, *Jatropha, Parthinium* and *Anona* showed maximum mortality and weight reduction of larvae, were true in adsorbed, non-adsorbed and crude samples. Compatibility of these potential biowashes has to done with other entomopathogenic microorganisms.

<div align="right">S Gopalakrishnan</div>

Milestone Insect pest and disease diagnostic tools and pest population dynamics models in relation to climatic changes developed 2011

Achievement of Output Target:
50%
In order to generate the information on the population dynamics of key insect pests of ICRISAT mandate crops, an attempt has been made to summarize the historic data on insect pests available with ICRISAT. The pest data has been summarized according to the standard week to look into the possible role of climatic factors on these key pests.

Participating Countries:
India

Participating Partners:
ANGRAU, CRIDA, IIIT

Progress/Results:
Pest surveillance data collected from 1991 to 2008 at ICRISAT on key pests of groundnut, chickpea and pigeonpea crops has been summarized according to standard week. In order to define the population dynamics of key species on various crops, and the effects of climate change on various insect pests dynamics, the groundnut data from 1991-2001 was subjected to various abiotic factors such as rainfall, minimum and maximum temperatures and relative humidity (%) and the inferences were drawn. At present the analysis of chickpea data up to 2008 is in process through a research scholar's project.

Special Project Funding:
None

<div align="right">GV Ranga Rao</div>

Activity 6.3.5.2 IPM Develop strategies for deployment of insect resistant transgenic crops for pest management and their bio-safety to nontarget organisms

Milestone Compatibility of host plant resistance with natural enemies and insecticides studied 2010

Achievement of Output Target:
75%
IPM strategies were developed for sweet sorghum. The experiments will be continued during 2010

Participating Countries:
India

Participating Partners:
Members of Sorghum Hybrid Parents Consortium

Progress/Results:
Monitoring insect pest incidence in monthly plantings of sweet sorghum: To assess the possibility of continued planting and availability of sweet sorghum stalks for ethanol production, seven sweet sorghum cultivars (five hybrids and two varieties) were planted at monthly intervals in deep black vertisols. There were three replications in a randomized complete block design for each planting. The pest incidence was monitored at monthly intervals, and the severity of insect pest damage was rated visually on a 1 to 9 scale (1 = <10% plants infested, and 9 = > 80% plants infested). The crop planted in May and June had the least damage by shoot fly, *Atherigona soccata*, sugarcane aphid, *Melanaphis sacchari*, armyworm, *Mythimna separata*, shoot bug, *Peregrinus maidis*, sorghum midge, *Stenodiplosis sorghicola*, and head bug, *Calocoris angustatus*. However, moderate levels of stem borer damage were recorded in these plantings (DR 2.33 to 2.67). Shoot bug and head bug incidence was high in the crop planted in July; while shoot fly (DR 2.67 – 5.0), aphid (DR 5.33 – 7.0), head bug (DR 2.0 – 4.33), midge (DR 1.0 – 2.33), and shoot bug (DR 3.33 – 7.33) damage was high in the August planting. Shoot fly incidence was very high (DR 8.67 to 9.0) in the September planting, while that of other insects was low to moderate. The results suggested that it is better to plant sweet sorghums during May to June, and in September (with adequate control of sorghum shoot fly) for ethanol production.

Integrated pest management in sweet sorghum: To develop a schedule for controlling sorghum shoot fly, *Atherigona soccata*, and spotted stem borer, *Chilo partellus* – the major stalk yield limiting factor in sweet sorghum, one hybrid (ICSA 479 x SSV 84), and three varieties (ICSV 700, ICSV 93046, and SP 4511-1), along with one shoot fly/stem borer susceptible, but midge-resistant high yielding variety (ICSV 745) were tested under insecticide treated and untreated conditions. The insecticide treatments included seed treatment with imidachloprid (4.8 g *ai* kg^{-1} seed), thaimethoxam (3.5 g *ai* kg^{-1} seed), fipronil (0.3 g *ai* kg^{-1} seed) granular application of carbofuran granules in the plant whorl (5 to 7 granules per plant at 7 days after seedling emergence for shoot fly, and 3 days after artificial infestation with neonate larvae of stem borer), and foliar sprays of deltamethrin (12 g *ai* ha^{-1}), methomyl (500 g *ai* ha^{1}), and endosulfan (700 g *ai* ha^{-1}). Untreated plots served as a control. There were three replications for all varieties and insecticide treatment combination in a randomized complete block design. Observations were recorded on shoot fly incidence at 14 and 21 days after seedling emergence and leaf damage and deadheart formation by stem borer at 25 days after artificial infestation. Overall resistance to shoot fly and stem borer damage was recorded maturity on a 1 to 9 scale (taking into account the number of main plant and tiller stalks, and the stalks with productive panicles). Data were also recorded on shoot bug and sugarcane infestation, and productive tillers and/or stalk and grain yield.

Imidachloprid, fipronil, and thaimethoxam as seed treatments were quite effective in controlling shoot fly, *A. soccata* damage in different cultivars of sweet sorghum (12.84 to 35.59% plants with deadhearts). The genotypes ICSV 700 and ICSV 93046 were least susceptible to shoot fly (21.48 to 32.40% plants with deadhearts compared to 73.86% deadhearts in SSV 84) and sugarcane aphid and shoot bug (damage rating <4.0), both under protected and unprotected conditions. These genotypes in combination with imidachloprid and thiamethoxam kept

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the shoot fly damage under check (12.84 to 17.14% plants with deadhearts compared to 47.32% in SSV 84), and can be used for integrated management of this pest. Deltamethrin and methomyl showed moderate activity, while endosulfan, fipronil, and carbofuran granules applied in soil were ineffective. Numbers of harvestable heads were more in the hybrid ICSA 479 x SSV 84 and ICSB 93046 than in SSV 84.

Granular application of carbofuran granules in the plant whorls three days after artificial infestation, and foliar sprays of deltamethrin and methomyl (0.0 to 4.65%, 0.0 to 1.08%, and 0.0 to 11.89% plants with deadhearts, respectively, compared to 3.79 to 60.20% plants with deadhearts in the untreated control) were highly effective for controlling damage by the spotted stem borer, *Chilo partellus*. Endosulfam sprays were moderately effective (2.08 to 22.99% plants with deadhearts), while imidachloprid, thiamethoxam, and fipronil seed treatments were ineffective for stem borer control (17.23 to 74.60% plants with deadhearts). Stalk yield was also greater in the carbofuran, deltamethrin methomyl treated plots than in the other treatments. Deadheart incidence was lower in ICSV 700 and ICSV 93046 as compared to SSV 84 under untreated conditions, as well as in insecticide treated plots. ICSA 479 x SSV 84 and SP 5411-1 suffered moderate levels of stem borer damage. Grain yield was significantly greater in the ICSA 479 x SSV 84 and ICSV 745 (18.00 to 33.83 q ha^{-1}) across insecticidal treatments) as compared to that of SSV 84 (6.78 to 14.94 q ha^{-1}).

HC Sharma, P Srinivasa Rao and BVS Reddy

Milestone Compatibility of transgenic crops and insecticides for pest management their impact on species diversity assessed 2011

Achievement of Output Target:
80%
IPM modules for pest management in sweet sorghum are being developed, use on transgenics in IPM assessed, and the interactions of transgenic crops with non-target insects are being studied

Participating Countries:
India

Participating Partners:
National Research Center for Sorghum

Progress/Results:
Monitoring insect pest incidence in monthly plantings of sweet sorghum: To assess the possibility of continued planting and availability of sweet sorghum stalks for ethanol production, seven sweet sorghum cultivars (five hybrids and two varieties) were planted at monthly intervals in deep black vertisols. There were three replications in a randomized complete block design for each planting. The pest incidence was monitored at monthly intervals, and the severity of insect pest damage was rated visually on a 1 to 9 scale (1 = <10% plants infested, and 9 = > 80% plants infested). The crop planted in May and June had the least damage by shoot fly, *Atherigona soccata*, sugarcane aphid, *Melanaphis sacchari*, armyworm, *Mythimna separata*, shoot bug, *Peregrinus maidis*, sorghum midge, *Stenodiplosis sorghicola*, and head bug, *Calocoris angustatus*. However, moderate levels of stem borer damage were recorded in these plantings (DR 2.33 to 2.67). Shoot bug and head bug incidence was high in the crop planted in July; while shoot fly (DR 2.67 – 5.0), aphid (DR 5.33 – 7.0), head bug (DR 2.0 – 4.33), midge (DR 1.0 – 2.33), and shoot bug (DR 3.33 – 7.33) damage was high in the August planting. Shoot fly incidence was very high (DR 8.67 to 9.0) in the September planting, while that of other insects was low to moderate. The results suggested that it is better to plant sweet sorghums during May to June, and in September (with adequate control of sorghum shoot fly) for ethanol production.

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Impact of transgenic cottons on biological control organisms (parasitoids and predators), arthropod biodiversity, and toxin flow in insect fauna: The information on impact of transgenic cottons on biological control organisms (parasitoids and predators), arthropod biodiversity, and toxin flow in insect fauna have been published in peer reviewed journal, and abstract and experimental details are hereunder. The seeds of *Bt*-transgenic MRC 7201 BGII and the non-transgenic counterpart were sown in two modules: i) Protected (seed treatment + insecticide sprays starting from 75 days after seedling emergence (DAE)), and ii). unprotected control, on ridges 75 cm apart, and spaced at 50 cm on an area of 325 m^2. Impact of *Bt* cotton and insecticide applications on the aerial arthropods was assessed through counting the numbers of arthropod species and their abundance on 25 plants tagged at random in the middle two rows of sampling sub-plots in each treatment at fortnightly intervals starting from 30 to 135 DAE, and there were five sampling sub-plots for each treatment. Influence of *Bt*-transgenic and/or an insecticide application on the arthropod biodiversity was judged through Simpson's diversity index. Species richness of plant inhabiting arthropods was similar in *Bt*-transgenic and non-transgenic cotton, and a total of 18 arthropod species representing Lepidoptera, Coleoptera, Hemiptera, Homoptera, Hymenoptera, Arachnida, and Dictyoptera were observed and their relative abundance in different treatments was recorded during the experimental period. The Simpson's index of diversity of aerial arthropods ranged between 0.69 to 1.00 in *Bt* cotton + protected, 0.67 to 1.00 in *Bt* cotton + unprotected, 0.77 to 1.00 in non-*Bt* cotton + protected, and 0.75 to 1.00 in non-*Bt* cotton + unprotected treatments. Simpsons's index of diversity for hemipterans in *Bt*-cotton than on non-*Bt* cotton was lower both under insecticide protected and unprotected treatments, suggesting significant influence of *Bt*-transgenic cotton and insecticide applications on the hemipterans. This reduction in diversity index of hemipterans in *Bt*-transgenic over the non-*Bt* cotton was largely due to high numbers of leafhoppers in *Bt*-transgenic cotton. However, no significant influence of *Bt*-transgenic cotton and/or insecticide applications was observed on the Simpson's index of diversity for other aerial arthropods.

Impact of *Bt*-transgenic cottons on soil dwelling insects: The seeds of *Bt*-transgenic MRC 7201 BGII and the non-transgenic counterpart were sown in two modules: i) Protected (seed treatment + insecticide sprays starting from 75 days after seedling emergence (DAE)), and ii). unprotected, on ridges 75 cm apart, and spaced at 50 cm on an area of 325 m^2 during the 2008 and 2009 cropping seasons. The results of 2008 studies are reported hereunder. To monitor the impact of *Bt* cotton and insecticide applications on the numbers of soil dwelling arthropod species and their abundance, five pitfall traps were installed in each treatment. These traps were operated at fortnightly intervals throughout the crop season (30 to 165 DAE). The arthropod species collected from the traps were recorded and sorted according to insect orders. Influence of *Bt*-transgenic and/or an insecticide application on the arthropod biodiversity was judged through Simpson's diversity index. Species richness of soil dwelling arthropods was similar in *Bt*-transgenic and non-transgenic cotton, and a total of 64 arthropod species representing Lepidoptera, Coleoptera, Hemiptera, Homoptera, Hymenoptera, Dictyoptera, Dermaptera, Diptera, and Arachnida were observed and their relative abundance in different treatments was recorded. The Simpson's index of diversity of soil dwelling arthropod species ranged between 0.90 to 1.00 in *Bt* cotton + protected, 0.89 to 1.00 in *Bt* cotton + unprotected, 0.87 to 1.00 in non-*Bt* cotton + protected, and 0.88 to 1.00 in non-*Bt* cotton + unprotected treatments. Simpsons's index of diversity for coleopterans was more in *Bt*-cotton than on non-*Bt* cotton both under insecticide protected and unprotected treatments, suggesting significant influence of *Bt*-transgenic cotton and insecticide applications on the soil dwelling coleopterans. However, no significant influence of *Bt*-transgenic cotton and/or insecticide applications was observed on the Simpson's index of diversity for other soil dwelling arthropods. The observations on 2009 experiment are under progress.

Influence of abiotic factors on the expression of *Bt* in different parts of transgenic cottons and their reaction to *H. armigera*: Expression of *Bacillus thuringiensis* δ-endotoxin Cry1Ac toxin protein in transgenic cotton hybrids was studied across a range of environmental conditions between January to September 2009. For this purpose, two transgenic cotton hybrids (Mech 184 and NCS 207) and their non-transgenic version were planted in the pots. A total of 15 plants (consisting of fifteen replications) were maintained for each test hybrid till the plant maturity during each planting date under net house conditions. Leaves from each planting were bioassayed against the neonate larvae of the bollworm *Helicoverpa armigera*, while the squares and bolls were bioassayed with 2nd instar *H. armigera* larvae. Amount of *Bt* protein produced in different parts were monitored through semi-quantitative ELISA. There were no significant differences for leaf damage rating, larval survival and weight gain by *H. armigera* larvae on leaves, squares and bolls among the genotypes, however, it varied significantly between *Bt* and non-*Bt* cottons and among different planting dates. The larval survival and weight gain were significantly more on non-*Bt* than on *Bt* cottons across the planting dates. Among the plant parts, the larval survival and weight gain were significantly more on bolls followed by squares and leaves. There was significant variation in *Bt* protein production in different plant parts during different planting dates. Significantly more *Bt* protein was detected in leaves followed by square leaflet, bolls, rind, squares and the endoplasm across different planting dates. This variation in expression of *Bt*-protein in different plant parts across planting dates might be because of the influence of abiotic factors. The correlation coefficients of *Bt*-protein expression in leaves, squares and bolls of *Bt*-cotton were positive with morning relative humidity, in leaves with evening relative humidity, and in bolls with bright sunshine. However, the correlation coefficients of *Bt*-protein expression in leaves, squares and bolls of *Bt*-cotton were negative with evaporation, minimum and maximum temperature, rainfall, solar radiation, and wind velocity. These studies have implications for understanding the effect of climate change on the efficacy of transgenic plants for pest management, and needs to be repeated to confirm such effects.

Host plant preference and population build up of *Helicoverpa armigera* on different crops

Experimental plots: A field experiment was conducted on host plant preference and population build up of *Helicoverpa armigera* using seven host plants viz., chickpea, pigeonpea, sorghum, pearl millet, groundnut, cotton, and sunflower during the postrainy 2008 and 2009 seasons. Each experimental host plant was planted in a 12 row plot of 9 m length. There were four replications in a randomized completely block design (RCBD). The observations were recorded on numbers of *H. armigera* eggs and larvae on total plants in middle 4-rows of 4 m length from each plot starting from 30 days after germination to crop maturity at fortnightly intervals. Crops x observation dates interaction effects for numbers of *H. armigera* eggs and larvae were significant during both 2008 and 2009 cropping seasons.

The host crops preferred for egg laying by *H. armigera* were in the order of pigeonpea>*Bt* cotton>non-*Bt* cotton>sunflower>groundnut>pearl millet>sorghum, however, the numbers of *H. armigera* larvae on different crops varied in the order of pigeonpea>sorghum>non-*Bt* cotton>sunflower>groundnut>sorghum>pearl millet>*Bt*-cotton, during 2008. During, 2009, the host crops preferred for egg laying by *H. armigera* were in the order of pigeonpea>*Bt* cotton>non-*Bt* cotton>sunflower>groundnut>pearl millet>sorghum; and the numbers of *H. armigera* larvae on different crops varied in the order of pigeonpea>sunflower>pearl millet>groundnut>non-*Bt* cotton>sorghum>*Bt*-cotton. Maximum numbers of *H. armigera* eggs were found in November and least in August; and the numbers of *H. armigera* larvae were in the order of November>December>September>October>August during both 2008 and 2009 cropping seasons.

ICRISAT research farm: *Helicoverpa armigera* population build was monitored in the ICRISAT research farm on the available *H. armigera* host plants between Feb to May 2009. The observations were recorded on numbers of eggs and larvae of *H. armigera* on 10 randomly selected plants at 10 different locations at fortnightly intervals. A total of eight host crops were under observation during the studies. There was significant variation in numbers of *H. armigera* eggs and larvae on different crops. The host crops preferred for egg laying by *H. armigera* were in the order of pigeonpea>sunflower>chickpea>groundnut>pearlmillet>safflower>sorghum>tomato, however, the numbers of *H. armigera* larvae on different crops varied in the order of sunflower > chickpea > pigeonpea > safflower > groundnut > sorghum > pearl millet > tomato, during the observation period. Maximum numbers of *H. armigera* eggs were found in April and least in May, however, maximum numbers of *H. armigera* larvae were recorded during February followed by March>April>May during the study period. These variations in *H. armigera* eggs and larvae on different crops and during different months might also be because of availability of numbers of host crops and their susceptible stage, and needs further studies to confirm such trends.

Farmer's fields around ICRISAT: *Helicoverpa armigera* population build was monitored in the farmer's fields around ICRISAT on the available *H. armigera* host plants between February to October 2009. The observations were recorded on numbers of eggs and larvae of *H. armigera* on 10 randomly selected plants at 10 different locations at fortnightly intervals. A total of 10 host crops were under observation during the studies. There was significant variation in numbers of *H. armigera* eggs and larvae on different crops. The host crops preferred for egg laying by *H. armigera* were in the order of pigeonpea>cotton>okra>groundnut>sunflower>pearl millet>tomato>chickpea> safflower>sorghum, however, the numbers of *H. armigera* larvae on different crops varied in the order of pigeonpea>chickpea>okra>sunflower>tomato>safflower>groundnut>sorghum>cotton>pearl millet, during the observation period. Maximum numbers of *H. armigera* eggs were found in September>October>April, while during other observation months the numbers of eggs were lower and were similar during other observation periods. The maximum numbers of *H. armigera* larvae were recorded during October followed by July>September>February>March>June>April>May>August. These variations in *H. armigera* eggs and larvae on different crops and during different months might also be because of availability of numbers of host crops and their susceptible stages during different observation periods, and need further confirmation.

HC Sharma and MK Dhillon

Output target 2011 6.3.5 IPM Bio-safety of transgenic crops to non-target organisms assessed

Achievement of Output Target:
50%
Effects of transgene products on the nontarget organisms have been evaluated under laboratory conditions, while work in continuing on the effects of transgenic crops on non-tartet organisms under field conditions.

Participating Countries:
None

Participating Partners:
None

Progress/Results:
Effect of *Bt*-transgenic cottons on management of *Helicoverpa armigera*, and the abundance of non-target insect pests and natural enemies under farmer's field conditions: The *Bt*-transgenic and non-transgenic cottons were surveyed at 14 locations from Andhra Pradesh, Maharashtra and Karnataka under farmer's field conditions for natural parasitization of eggs and larvae of *H. armigera* (9 locations), efficacy of *Bt* cottons in management of bollworms, effects on non-target pests and natural enemies during the 2009 cropping season. Although, there were significant differences in *H. armigera* egg parasitism across locations and between *Bt*-transgenic and non-transgenic cottons. Egg parasitism was significantly more on *Bt*-transgenic than on non-transgenic cottons across locations. Parasitization of *H. armigera* eggs was abundant (>50%) and significantly more in Parbhani, Medak and Nizamabad districts as compared to other observation sites of Andhra Pradesh, Maharashtra and Karnataka. *Trichogramma* spp. was the only egg parasitoid found to parasitize the eggs of *H. armigera* across states and regions. No enough *H. armigera* larvae were found on the *Bt* cottons during the survey, and were not able to draw any conclusion on effects of *Bt* cottons on the *H. armigera* larval parasitism. There were significant differences in numbers of *H. armigera* eggs and larvae across locations and between Bt-transgenic and non-transgenic cottons. The numbers of *H. armigera* eggs were significantly more on *Bt* than on non-*Bt* cottons, while reverse was the trend for *H. armigera* larvae across locations. There was significant variation in numbers of *Spodoptera litura* larvae across locations, while no significant differences were observed in numbers of *S. litura* larvae on *Bt* and non-Bt cottons. The locations x *Bt* interactions were also significant for boll and square damage by bollworm, and the bollworm damage on bolls and squares were significantly more on non-*Bt* as compared to *Bt* cottons. Although, there was significant variation in abundance of sucking pests [jassids, whiteflies, aphids, and mealy bug] across locations and between *Bt* and non-*Bt* cottons, the differences between *Bt* and non-*Bt* cottons were marginal. There was significant variation in abundance of natural enemies - coccinellids, chrysopids, and spiders across locations, however, no significant differences were observed for their numbers on *Bt* and non-*Bt* cottons.

HC Sharma and MK Dhillon

Output target 6.3.6. CAP Capacity of NARS/NGOs enhanced, and products/information on improved cultivars and crop production technologies disseminated in Asia

Activity 6.3.6.1 CAP Capacity building and dissemination of information on improved cultivars/technologies to NARS/NGOs/farmers in Asia

Output target 2010 6.3.5 CAP At least 20 Ph.D. students, apprentices and technicians trained in various aspects of crop improvement, biotechnology and crop management

Achievement of Output Target (%):
70%

Training was provided to more than 20 students/staff during 2009. Some students will conclude research during 2010.

Participating Countries:
Ethiopia, India, Kenya, Myanmar, Nepal, Tanzania

Participating Partners:
NARS in above countries

Special Project Funding:
Tropical Legumes II

Progress/Results:
Chickpea
Nine scientists/researchers from Myanmar (3), Ethiopia (2), Tanzania (2), and Kenya (2) were provided 1-3 months training on chickpea breeding and seed production at ICRISAT-Patancheru (Table 6.9). The trainees were given lectures and hand on training on various aspects of chickpea improvement using both conventional and biotechnological methods; screening methods for resistance/tolerance to abiotic and biotic stresses; integrated crop management including IPM; and production processing and storage of seed.

Table 9. Participants of training program on chickpea breeding and seed production.

Name of trainee	Gender	Country	Designation and affiliation	Duration of training
Million Eshete Wolde	Male	Ethiopia	Chickpea and Lentil Research project Coordinator, Debre Zeit Agricultural Research Center, Debre Zeit.	1 month (6 Jan-5 Feb 09)
Abebe Atilaw Gizaw	Male	Ethiopia	Coordinator, Seed multiplication and Dissemination, Debre Zeit Agricultural Research Center, Debre Zeit.	1 month (6 Jan-5 Feb 09)
Epifania Elias Temu	Female	Tanzania	Principal Agriculture Research Officer, Lake Zone Agricultural Research Institute, Ukiriguru, Mwanza.	1 month (6 Jan-5 Feb 09)
Stella Gamaliel Chirimi	Female	Tanzania	Principal Agricultural Field Officer, Lake Zone Agricultural Research Institute, Ukiriguru, Mwanza	1 month (6 Jan-5 Feb 09)
Bernard Kibet Towett	Male	Kenya	Senior Technician, Dept. of Crops, Hort. and Soil Science, Egerton University, Nairobi.	1 month (6 Jan-5 Feb 09)
Wilson M Thagana	Male	Kenya	Senior Research Officer, Kenya Agricultural Research Institute, Nairobi.	1 month (6 Jan-5 Feb 09)
Thin Maw Oo	Female	Myanmar	Junior Research Assistant, Zaloke Research Farm, Dept. of Agricultural Research, Monywa Township, Mandalay Division	3 months 1 Dec 08 to 5 Mar 09
Yin Yin Aye	Female	Myanmar	Junior Research Assistant, Myingyan Research Farm, Mandalay Division, Dept. of Agricultural Research, Yezin	3 months 1 Dec 08 to 5 Mar 09
Khin Thida Hlaing	Female	Myanmar	Junior Research Assistant, Pangone Research Farm, Dept. of Agricultural Research, Ye Oo Township, Sagaing Division	3 months 1 Dec 08 to 5 Mar 09

In addition to these, we accommodated one Ph D student (S Srinivasan) from University of Western Australia and one M Sc student (Tadesse Safera) from Haramaya University, Ethiopia for thesis research.

CLL Gowda, PM Gaur and Shailesh Tripathi

Groundnut
Eight researchers from India, Myanmar and Nepal were accommodated as Research/Visiting Fellows and provided training in groundnut breeding methodology (Table 6.10).

Table 10. Participants of training program on groundnut breeding methodology.

Name	Country	Category	From	To	Training in
Mr M Manjunatha	India	Research Fellow	16-Mar-09	14-Apr-09	Groundnut Breeding Methodology
Mr Mirza Shajiulla Baig	India	Research Fellow	16-Mar-09	14-Apr-09	Groundnut Breeding Methodology
Mr Fakirsab Chandsab Nadaf	India	Research Fellow	16-Mar-09	14-Apr-09	Groundnut Breeding Methodology
Mr Girish Kumar	India	Research Fellow	16-Mar-09	14-Apr-09	Groundnut Breeding Methodology
Ms Sein Leai Mon	Myanmar	Research Fellow	7-Sep-09	28-Dec-09	Groundnut Breeding Methodology
Ms Phyu Phyu Moe	Myanmar	Research Fellow	7-Sep-09	28-Dec-09	Groundnut Breeding Methodology
Mr Om Narayan Chaudhary	Nepal	Visiting Fellow	15-Sep-09	14-Oct-09	Groundnut Breeding Methodology
Mr BC Khim Bahadur	Nepal	Visiting Fellow	15-Sep-09	14-Oct-09	Groundnut Breeding Methodology

Crop Management
- One Asstt. Research Scientist from SDAU, Gujarat was given 10 days training on screening techniques and management of pigeonpea diseases through host plant resistance.
- Imparted training to Dr NH Ghimire, Entomologist from PARS, Nepalganj, Nepal on the integrated disease management of chickpea and Pigeonpea.

Suresh Pande and Mamta Sharma

Wide Hybridization

Six apprentices (students) were trained in various aspects of wide crosses in legumes, cytology and evaluation of interspecific derivatives for various traits.

<div align="right">Nalini Mallikarjuna</div>

IPM

Conducted training program on IPM in sweet sorghum (100 participants).

<div align="right">HC Sharma</div>

Milestone Farmer-friendly literature on crop management and seed production technology published and distributed to NARS 2009

Achievement of Output Target:
100%

Participating Countries:
India, Nepal and Vietnam

Participating Partners:
ICAR, SAUs and NGOs in India, NARC and NGOs in Nepal and VAAS in Vietnam

Special Project Funding:
IFAD, TL II, ISOPOM and the OPEC Fund

Progress/Results:
Groundnut
The farmer-friendly literature in vernacular languages on description of farmer-preferred varieties and integrated crop management and seed production technologies has been published by our collaborators and distributed to farmers and other stakeholders.

<div align="right">SN Nigam</div>

Chickpea
A folder on "Rainfed rice based chickpea production technology" in Hindi including management of pod borer was prepared and distributed to the rainfed rice fallow-chickpea farmers of Chattisgarh and Madhya Pradesh.

<div align="right">Suresh Pande and Mamta Sharma</div>

Output target 2010 6.3.5 CAP Training courses in application of molecular markers in crop breeding programs conducted for NARS staff

Achievement of Output Target:
80%
Training courses scheduled for 2009 were completed. Additional training courses will be conducted in 2010.

Participating Countries:
Botswana, Eritrea, Ethiopia, Ghana, India, Kenya, Morocco, Nigeria, Tanzania

Participating Partners:
NARS from above countries

Progress/Results:
The Center of Excellence in Genomics (CEG) at ICRISAT to strengthen the molecular breeding program in India, hosted two training courses in 2009, sponsored by Department of Biotechnology, Government of India. Some African participants were supported by KirkHouse Trust, UK, and three Indian participants were supported by Indian Council for Agricultural Research. The Fifth Training Course training course on "*Molecular Marker Technology or Crop Improvement*" was held during 18-29 May 2009 and the Sixth ICRISAT-CEG training course on "*Application of Genomics Technologies in Plant Breeding*" was held during 16-27 Nov 2009, at ICRISAT Patancheru. A total of 53 participants (including 11 overseas participants from 8 African countries Botswana, Eritrea, Ethiopia, Ghana, Kenya, Morocco, Nigeria and Tanzania) participated in these two training courses. The other 45 participants are from ICAR centers, State Agricultural Universities, Private Sector, Research Foundations, CSIR Institutes, and Governmental Organizations.

The CEG will host such type of courses in the coming years and the course will be notified in our web site www.icrisat.org/ceg during March and July in 2010.

Special Project Funding:
Department of Biotechnology, Government of India

<div align="right">RK Varshney, A Rathore, S Senthilvel, CT Hash, BM Prasanna,
Dave Hoisington, other scientists and staff</div>

Output target 2011 6.3.5 CAP Training course on screening for resistance to Helicoverpa organized

Achievement of Output Target:
100%
A training course on screening for resistance to *Helicoverpa armigera* from India and Kenya has been conducted.

Participating Countries:
India, Kenya

Participating Partners:
ICAR and Egerton University

Progress/Results:
A training course has been organized to screen and breed for resistance to *Helicoverpa* using conventional and biotechnological approaches.

Special Project Funding:
ISOPOM project on *Helicoverpa* resistance.

HC Sharma

Output target 2011 6.3.5 CAP Training courses in mycotoxin detection technologies conducted for NARS staff

This training course will be organized in 2010 or 2011.

MTP Project 7: **Reducing Rural Poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and Products**

Project Coordinator: **SP Wani**

Major findings

- The African Market Garden (AMG) and Bioreclamation of Degraded Lands (BDL) have been refined and evaluated for scaling-up in different communities in WCA.
- The Comprehensive Assessment (CA) of watershed programs in India demonstrated and provided "concept of the proof" that integrated watershed management program (IWMP) could become a growth engine of sustainable development in dryland areas of India as well as other Asian countries. Large scope exists to enhance the performance of 68 per cent of watershed projects in India through bringing in science-led development options, enabling policies and institutional mechanisms to unlock the vast untapped potential of rain-fed agriculture.
- Capacity building is the weakest link to scale-up the IWMP in the region and availability of baseline data and scientific monitoring (biological, institutional and social parameters) systems need to be strengthened along with capacity building measures and increased investments per unit of land as well as total investments in drylands to upgrade rain-fed agriculture.
- Intensification with high-value vegetables in watersheds with increased water availability resulted in occurrence of pesticide residues in significant proportion of samples from IPM and non-IPM plot samples suggesting urgent need to work on development and dissemination of environment-friendly pest management options.
- A unique institutional mechanism for development of common property resources (CPRs) for growing biodiesel plantations have been developed by ICRISAT along with the Government of Andhra Pradesh and other consortium partners. The landless farmers manage the natural resources of the CPRs and get usufruct rights over the plantation for harvesting the produce to add to their family incomes.
- Evaluation of 99 genotypes of *Jatropha curcas* in field and also using molecular techniques such as AFLP revealed genotypic diversity for oil content and other growth and yield parameters. The genotypes with combination of desirable traits are identified to harness their potential for crop improvement.
- Financial analysis of Jatropha production scenario from degraded waste lands indicated that Jatropha methyl ester (biodiesel) produced from the seeds harvested from the waste lands at 1 t ha^{-1} productivity could be economically viable when crude oil prices would be around US$ 75 per barrel. If straight vegetable oil is used as a source of energy than Jatropha oil will be economically viable far below US$ 75 per barrel.
- We evaluated the best-bet management options for sweet sorghum both at on-station and on-farm. Early sowing in summer gave higher yields of stalk and juice. Application of 90 to 150 kgs N ha^{-1} and spray of growth hormone ethephon increased the juice yield of sweet sorghum. ICSA 52 x SPV 1411 gave the highest stalk and juice yield. In on-farm situation, stalk yield was 33.6 t ha^{-1} and juice yield of 11 t ha^{-1}. Total soluble sugars was not affected.

Output 7.1: African Market Garden technology strategy and knowledge database, developed, tested and promulgated with associated capacity development regionally in the SAT of the Sahel in collaboration with AVRDC and ICRAF and assessed in comparison with existing and new potential dryland alternatives

Output target 2009 7.1.1 Authoritative AMG strategy published and advocacy campaign for policy amendment completed (associated with the DMP SWEP)

Achievement of Output Target:
80%
The AMG is an integrated system and the research carried out on this system incorporates drip technology aspects, vegetables and fruit trees research, soil and water aspects and socio economic studies.

Activity 7.1.1.1 The African Market Garden (AMG)

Participating Countries:
Senegal, Mali, Burkina Faso, Benin, Niger

Participating Partners:
Israeli Embassy-Senegal, SELF-USA, farmers cooperatives and various NGOs

Progress/Results:
The AMG is a low-pressure drip irrigation system for small horticulture producers. It is an integrated system comprising of an irrigation system combined with a management package

In 2009 we established:
Two new pilot AMG sites in Niger, one utilizing solar energy and the other using artesian energy for water delivery
AMG project in north Benin was refined with communal system involving women groups
Established AMG (TIPA) project in Senegal with emphasis on installation of the AMG in schools and universities.
Precise economic and socio-economic analysis of the AMG was undertaken (Table 1)

Table 1. Economic analysis of four models of the AMG system compared with a traditional system.

	Traditional	African Market Garden system			
		Thrifty	Commercial	Cluster	Communal
	500 m²	80 m²	500 m²	10 x 500 m²	5000 m² for 10 prod.
	US$	US$	US$	US$	US$
Drip system	0	24	300	3,000	2,500
Reservoir[1]	50	56	300	560	2,000
Well/Borehole[2]	160	30	160	160	160
Pump[3]	335	30	335	335	335
PVC connections	33	10	33	792	60
Farming tools	170	48	173	651	651
Fence	70	25	70	249	226
Set-up cost	**818**	**223**	**1,371**	**5,746**	**5,932**
Annual costs	**665**	**98**	**547**	**5,094**	**5,094**
Gross revenues	**1,323**	**292**	**1,824**	**18,235**	**18,235**
Payback Period (years)	**1.2**	**1.2**	**1.1**	**0.4**	**0.5**
Return to Land ($/m²)	**0.9**	**1.7**	**2.1**	**2.4**	**2.4**
Return to Labor ($/mday)	**4.9**	**12.6**	**15.2**	**17.9**	**18.0**

[1] Thrifty and Cluster: 200 liter oil drum; Other systems: concrete reservoir

[2] Thrifty: Hand dug well < 4 m; Other systems: 110 mm hand drilled borehole to 12 m depth

[3] Thrifty: Manual pump; Other systems: 3 hp motorpump

The table clearly shows the "advantage of scale" expressed in both the Cluster and the Communal systems where payback period was reduced fom1.2 years for single AMG units to 5-6 months.

In November 2009, we received a small grant from AVRDC that allowed the initiation of the further trials.

<div align="right">Lennart Woltering</div>

Activity 7.1.1.2 Vegetables Research

Participating Countries:
Mali, Burkina Faso, Niger

Participating Partners:
APIPAC-Burkina**,** Union of Horticulture Cooperatives in Niger, APROPA and two other farmers Associations in Mali, WASA, AVRDC

Progress/Results:
Vegetables research is carried out in collaboration with an AVRDC vegetable breeder. The major achievement in this year was the proliferation of the Icrixina variety production in neighboring countries during the rainy season. The activities on breeding and selection of okra varieties for the various seasons and various traits were conducted along with improvement of the quality of okra fruit.

<div align="right">Sanjeet Kumar</div>

Activity 7.1.1.3 Fruit Trees Research
Task: Domestication of priority fruit plants in the Sahel to improve nutrition and household income

Participating Countries:
Niger

Participating Partners:
ICRAF

Progress/Results:
Identification of suitable rootstock for improved Ziziphus propagation
Improved *Ziziphus* varieties commonly called the Sahel Apple have been introduced from India to West Africa were it is usually grafted on *Ziziphus mauritiana* rootstock. The slow growth of *Z. mauritiana* during the nursery phase makes it unattractive to producers of grafted plants. We evaluated the performance of four Ziziphus species as rootstocks.
- The first trial was established to evaluate performance of grafted plants using different rootstock (*Ziziphus mauritiana, Z. rotundifolia, Z. spin- christi* and *Z. mucronata*). A second treatment was applied in the field to test effect of water harvesting structures on tree growth and fruit yield. The results of two years assessment showed significant effect of water harvesting

structures on tree growth. Comparison of growth performance of the four Ziziphus species indicates that *Z. spina-christi* is likely to the best rootstock for improved *Z. mauritiana*. Fruit yield data will be used to confirm this result.
- Draft paper in progress for submission to peer reviewed journal

<div align="right">Albert Nikiema</div>

Activity 7.1.1.4 Domestication of *Saba senegalensis* for fruit production

Participating Countries:
Niger

Participating Partners:
ICRAF

Progress/Results:
Saba senegalensis is an indigenous fruit plant highly valued by local people in the semi arid West Africa. Fruits of this plant are sold in most city markets of West Africa for juice production and as food additive. It provides for local people during fruiting season. Two experiments to monitor fruiting performance of *Saba senegalensis* under irrigated conditions and to evaluate variability between provenances were conducted.

Preliminary results shows that Saba plants started giving fruits two years after planting and data on phenology indicate that flowering occurs all year round with a peak period in June. Fruits mature only in July-August after a long period of development, which can last for 12 months. Fruit production per plant varies remarkably ranging from 100 gr. to more than 8 kg. Mean weight of fruits is about 200 g with pulp representing 20-30% of the fruit weight. The seeds occupy 10-20% of the fruit weight and the fruit coat 50-60%. Total soluble solids (TSS) fluctuate between 18 and 26. A large variability in fruit size, shape, yield and quality between individual trees indicates a great potential for *Saba senegalensis* domestication.

<div align="right">Albert Nikiema</div>

Activity 7.1.1.5 Development of the Bio-Reclamation of Degraded Lands (BDL) system

Participating Countries:
Niger

Participating Partners:
NGOS 9ASV, CDR, CADEV)

Progress/Results:
The BDL is a new production system aiming at the reclamation of degraded crusted soils using a series of traditional water harvesting techniques and high value hardy vegetables and fruit trees.
Vegetables are panted in planting pits (zaï holes) and trees are planted in micro-catchments (demi lunes). The most common vegetables species are okra, Roselle and *Senna obtusifolia* a local traditional leafy vegetable. The trees species used are the domesticated *Ziziphus mauritiana* (the Apple of the Sahel) and *Moringa stenopetala*

Detailed research is being carried out at a 1.5 hectare BDL site at the Sadore village by ICRISAT research station in Niger. Pilot fields were set up in the Dosso, Tillabery and Zinder regions.
In 2009 we concentrated on the economic and socio economic evaluation of the BDL at the Sadore village.

It was found that the BDL is highly profitable giving a internal rate of return of about 30%
An econometric analysis (Table 2) shows that the results from the simple regression suggest (at least at 10% level) that the factors that most determine the probability of having high NPV were number of schooling years (+), number of labor in household (+), gross revenue of the household (+) , planting date (-), density of planting pits (+), quantity of seed used (-) and quantity of manure used (-)

Table 2. Econometric analysis of the Sadore village BDL.

Variables	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Age	-0.0212616	0.0750873	-0.28	0.783	-0.1911209	0.1485976
Ethnicity group	-0.0425459	0.1361873	-0.31	0.762	-0.350623	0.2655312
Occupation	0.1398447	0.1376388	1.02	0.336	-0.1715159	0.4512052
Number of schooling years	0.0849665	0.0429864	1.98	0.079	-0.0122754	0.1822084
Number of labor in household	0.3295393	0.1477632	2.23	0.053	-0.0047243	0.6638029
Gross revenue of the household (ln)	0.1985818	0.0682359	2.91	0.017	0.0442215	0.3529422
Value of assets in household (ln)	-0.0171487	0.0507365	-0.34	0.743	-0.1319227	0.0976253
Planting date	-0.231577	0.1121111	-2.07	0.069	-0.4851901	0.022036
Density of planting pits	0.0142537	0.0028276	5.04	0.001	0.0078572	0.0206503
Quantity of seed used (ln)	-0.5620787	0.2003688	-2.81	0.021	-1.015344	-0.108813
Quantity of manure used (ln)	0.0075209	0.190814	0.04	0.969	-0.4241304	0.4391722
Constant	6.317022	2.284763	2.76	0.022	1.14853	11.48551

<div align="right">Dov Pasternak and J Ndjeunga</div>

Output target 2009 7.1.2 Single plant selections of Okra and hot pepper made and distributed to partners for testing

Achievement of Output Target:
100%

Participating Countries:
Niger, Burkina Faso, Mali, Senegal

Participating Partners:
AVRDC, Various NGOS

Progress/Results:
The okra variety called Konni and the hot pepper variety called Safi were purified and tested in the African Market Gardens of Senegal, Benin and Niger. Konni okra was also tested under rainfed conditions by women groups.

The Konni Okra is a short-duration (54 days) variety with high yield and good quality fruit. Safi hot pepper is very pungent and a higher yielder.

Ninety producers from the Sahel were trained in the production of okra and hot pepper seeds and received the seeds of these varieties for multiplication.

Special Project Funding: WASA, AVRDC, Internal sources

<div align="right">Dov Pasternak</div>

Output target 2009 7.1.1 (Carried over from 2008) Documentation of processes, practices and learnings on African Market Garden for Sahelian countries

Achievement of Output Target:
100%

Participating Countries:
Senegal, Mali, Burkina Faso, Ghana, Benin, Niger

Participating Partners:
A wide range of NGOs, farmers associations

Progress/Results:
Documentation of AMG practices for women producers groups was carried out in Benin and accepted for publication in PNAS. Paper Title is "J. Burney, L. Woltering, M. Burke[3], R. Naylor, D. Pasternak. Solar-powered drip irrigation enhances food security in the Sudano-Sahel"

Documentation of the AMG process in the Sahel was carried out and summarized in the paper "L. Woltering, D. Pasternak and J. Ndjeunga. The African Market Garden: Development of an integrated horticulture production system for smallholder producers in West Africa" that was submitted to the Journal of Irrigation and Drainage for publication

Special Project Funding:
USAID, USADF, Government of Taiwan, SELF

<div align="right">Dov Pasternak</div>

Output 7.2: New approaches and technological options to create a strategy to diversify SAT systems using available water resources efficiently to grow high-value commodities that increase incomes for disadvantaged households identified and promoted with associated capacity building by consortium partners to Government agencies, donors, NGOs, and CBOs

Output target 2008 7.2.1 Inventory of alternative watershed practices for 4 Asian countries documented and made available globally

Achievement of Output Target:
100%

Activity 7.2.1.1 On-farm trials, for evaluation of various biological options to control lepidopteron insect pests and disease of tomato, Adarsha Watershed, Kothapally, Andhra Pradesh, India

Participating Countries:
India

Participating Partners:
READ, Adarsha Watershed Committee

Progress/Results:
Three tomato growing farmers participated in our trials in Adarsha Watershed at Kothapally village, Ranga Reddy district. They evaluated two treatments one being called "bio plots" and the second one was "farmers practice plots". Strict instructions were given to the farmers following the bio plots did not use any pesticides and fungicides, where various biological options tested at ICRISAT were applied to control *Helicoverpa* and other pests and diseases of tomato. In the farmer practice plots they used chemical pesticides and fungicides for controlling insect pests and diseases. Farmers produced 2.4% higher tomato yield in bio plots than the farmers practice. In addition farmers

<div align="right">283</div>

saved insecticide costs and minimized environmental pollution through pesticide contamination and spiders and coccins population were also found greater in bio plots over farmer practice plots whereas damage pods were found more in farmer practice plots over bio plots.

S Gopalakrishnan, GV Rangarao and SP Wani

Activity 7.2.1.2 Economic Surplus Approach for Impact Assessment of Watersheds

Participating Countries:
India

Participating Partners:
Center for Agriculture & Development Studies (CARDS)

Progress/Results:
Recognizing the importance of watershed development as a strategy of rural development, various agencies invest huge funds on watershed development. The watershed approach enables the planners to internalize such externalities and other linkages among agricultural and related activities. Experience shows that various watershed development program brought significant positive impact. Impact evaluations contribute to improve the effectiveness of policies and programs. Different methodologies have been used in the evaluation literature mainly the qualitative and quantitative methods. Choosing appropriate methodology for impact assessment of natural resource management interventions are essential.

This study outlined the various concepts and methods in watershed impact evaluation with examples were compared. The use of economic surplus approach with consumer and producers' surplus is compared with the conventional approach with only producers' surplus. Also incorporation of the rainfall variability in the watershed evaluation is demonstrated. A simple computer based watershed program incorporating the various components of the watershed development is also developed.

K Palanisami, D Suresh Kumar and SP Wani

Activity 7.2.1.3 Watershed Development in Northeast India: Impacts, Opportunities and Problems

Participating Countries:
India

Participating Partners:
NCAP, GoI

Progress/Results:
The Northeast region is endowed with problems of undulating topography, soil erosion, small landholdings, *jhume* (shifting) cultivation, although it has fertile lands, high and dependable rainfall and agriculturally-favorable climate which can serve as the best-bet for the development of watershed programs on a large scale. Although a number of impact assessment studies have been done in past by various researchers and organizations on the watershed development programs, no thorough study has been conducted on the impact of watershed development programs carried out in the Northeastern region. It is in this endeavor, a study was attempted to assess the impact of watershed development programs in the region. The study is based on the review of evaluation reports as well as the case studies carried out under the project. The study assessed the performance of watershed programs by employing meta-analysis of 37 watershed case studies and micro-level studies of four watersheds in the regions. The results of meta-analysis of 37 case studies showed that all the watersheds in Northeast region were economically remunerative with an average B:C ratio of 1.79 with the average internal rate of return of 19.4. Agricultural productivity was increased by 28.9 per cent along with increased cropping intensity of 24.67%. The watershed interventions also reduced the area under jhume cultivation.

FA Shaken, PK Joshi and SP Wani

Activity 7.2.1.4 Community watersheds for improved livelihoods through consortium approach in drought prone rainfed areas

Participating Countries:
India, China, Philippines, Thailand, Vietnam

Participating Partners:
CRIDA, GoI, APRLP, Sujala, BAIF, BAR, The Philippines, GAAS, UAAS, CAAS, China, VAAS, Vietnam

Progress/Results:
In rainfed agriculture, occurrence of droughts is a common feature and the frequency of droughts is expected to increase due to prevailing climate change. Watershed development is adopted as a drought proofing strategy for improving livelihoods. Watershed development approach has evolved from a compartmental approach of conserving soil and water to a more holistic and participatory livelihoods approach. The new approach calls for inputs from various institutions and actors for greater impact. ICRISAT led Consortium has developed an innovative community watershed management model involving participatory research and development. This approach developed at Adarsha Watershed, Kothapally in India and further scaled out in 368 watersheds in India, China, Philippines, Thailand and Vietnam has showed multiple impacts by increasing crop productivity by 2 to 4 folds, doubling the family incomes, enhancing biodiversity, enhancing community resilience to cope with changes including due to climate change, reducing run-off and soil losses, building institutions and developing local capacity.

Activity 7.2.1.5 Innovative watershed policies and institutions in India and increased investments in rainfed areas for improving livelihoods in dry land areas of India and China

Participating Countries:
China, India

Participating Partners:
CRIDA, GoI, APRLP, Sujala, BAIF, BAR, the Philippines, GAAS, UAAS, CAAS, China, VAAS, Vietnam

Progress/Results:
On-farm benchmark community watershed sites in India, China, Thailand and Vietnam demonstrated the power of science-led IGNRM approach for improving rural livelihoods and conserving natural resources. This participatory research and development (PR&D) approach triggered the interest amongst the policy makers in India and China and ADB for using innovations for scaling-up inclusive and sustainable growth in rainfed areas. The CA of rainfed agriculture in the SAT recommended small catchment/watershed approach with innovative institutional and policies for scaling-up the benefits to upgrade the rainfed agriculture.

Impressed with the evidence of sustainable intensification and diversification through watershed management (WM) availability, the GoI requested ICRISAT to undertake the CA of Watershed Programs in India. The CA of watershed programs concluded that community watershed can become the growth engine for sustainable development of drylands. The CA of watershed programs in India revealed that only <1 per cent of the watersheds were economically non-remunerative (B:C ratio <1). Average B:C ratio for the watershed programs based on the meta analysis of 636 case studies was 2 and recommended suitable changes in the approach, policies, and institutional mechanisms for enhancing the benefits of 68% watersheds. The CA made 25 recommendations to the MoA and MoRD. The Planning Commission, GoI, are converging all watershed programs under revised watershed guidelines, MoRD as the nodal ministry as Integrated Watershed Management Program (IWMP). The IWMP Common Guidelines adopted the science-based consortium approach, doubled investments (Rs. 6000 to 12000 ha^{-1}), increased duration (five to seven years), increased the size from 500 to 5000 ha and adopted the livelihood approach. Premier scientific institutions in India including ICRISAT represent on Central Level Nodal Agency which is the national body to implement the IWMPs. ICRISAT is assisting the GoI for the IWMP through technical backstopping and capacity building support. The long journey started with the strategic research passing through the PR&D – innovations for up-scaling the technologies for the desired impact through enabling policies and institutional changes has began the process of unlocking the potential of rain-fed agriculture in India and China.

Impressed with the results from the ICRISAT consortium benchmark watersheds at Lucheba and Xia xin cun in southern China Government of China and Asian Development Bank initiate a project to upscale the watershed approach. Based on the exemplary results from the work in China, Chinese Academy of Agricultural Sciences-ICRISAT and ICARDA have established the Center of Excellence in Dryland Agriculture (CEDA) for improving livelihoods in dryland areas.

Output Target 2009 7.2.1 Capacity-building for partners in crop diversification and the implementing of IGNRM practices

Achievement of Output Target:
80%
In continuation of our earlier efforts to build the capacity of our partners and lead farmers in the area of Integrated Genetic and Natural Resource Management (IGNRM) during 2009, four training courses for the partners and policy makers were conducted involving 100 trainees. Integrated Watershed Management was used as an entry point to improve livelihoods. In addition four field days involving 700 farmers were conducted to share the experiences of the benchmark watershed farmers. The concept of farmers facilitators and lead farmers was found very effective in villages of six districts in Karnataka, India.

Participating Countries:
Burkina, India, Mali, Niamey

Participating Partners:
GoI, CRIDA, NGOs

Progress/Results:
Three Training of Trainers (ToT) courses for senior policy makers in the area of Integrated Watershed Management Program (IWMP) were conducted. In all 70 master trainers were trained.

A team of 20 members of D1WM staff from Northeast states, who are engaged in *Jatropha* plantation activity, along with senior staff from of D1 Oils Fuel Crops visited ICRISAT on 20 January to know about current research activities on *Jatropha* at ICRISAT. They were explained about nursery raising techniques especially on raised beds, bed preparation, application of FYM, DAP and *Mycorrhiza* in the beds for good quality seedlings, precautions to be taken for transporting and planting bare root seedlings of *Jatropha* etc. They were also taken to biodiesel plantations and explained about agronomic practices like land preparation, pitting, spacing to be followed in different soil conditions, planting, fertilizer requirement, intercropping, soil and water conservation practices, plantation management, pruning and pest

and disease problems etc. They were happy with the visit and appreciated that topics were practical and exactly match with some of the problems what they have observed in the fields. It was a fruitful visit for exchanging information and knowledge.

For Jatropha cultivation for decentralized energy production under tribal village of Korba district in Chattisgarh, Training Needs Assessment was undertaken. Based on the TNA training course for the trainers training in Jatropha cultivation methods was conducted at ICRISAT, Patancheru during 9-12 December 2009 for 25 participants

Special Project Funding:
GTZ, DoLR, GoI, D1 oil fuel crops, SDTT

<div align="right">S Marimuthu, SP Wani and TK Sreedevi</div>

Output Target 2009 7.2.2 Balanced nutrient management options for vegetable cultivation evaluated

Achievement of Output Target:
90%
Results across the years need to be analyzed and synthesized.

Participating Countries:
India

Participating Partners:
BAIF, TSRDS, BAIF, PRADAN

Progress/Results:
Under Farmer Participatory Action Research Programme in the districts of Madhya Pradesh, Jharkhand and Rajasthan farmers have evaluated the response of vegetables to micronutrients and balanced nutrient management based on the soil analysis. Similarly, for enhancing water use efficiency low-cost and low pressure drip irrigation systems as well as normal drip with cluster of farmers are evaluated in two districts of Jharkhand. The results from the trials are awaited. Earlier two years results clearly demonstrated the benefits of balanced nutrient management including micronutrients on increased crop yield and incomes.

Special Project Funding:
SRTT, SDTT, GoI

<div align="right">SP Wani, KL Sahrawat, P Pathak and RC Sachan</div>

Output Target 2010 7.2.1 Potential proof of concept for use of environment-friendly alternative sources of energy using straight vegetable oil (SVO) to use as energy source

Achievement of Output Target:
50%
The CBO is formed and work on establishing energy generator is in progress. From 2010 rainy season, Jatropha seeds will be processed in Velchal village and we can assess the viability of this concept.

Participating Countries:
India

Participating Partners:
READ, GoAP, SKOl, GTZ

Progress/Results:
In Ranga Reddy district of Andhra Pradesh four years plantation of 300 ha on degraded common property resources (CPRs), decentralized environmental friendly alternative source of energy using straight vegetable oil (SVO) is being conceptualized through public private partnership mode. The partners in this initiative are Kirloskar Oil Engines Ltd (KOEL), ICRISAT, Community-based organizations (CBOs) of Velchal and GTZ. Under this initiative, Velchal gram panchayat has provided space for constructing 1000 sft building for housing, *Jatropha* oil extraction and Genset on straight vegetable oil. Velchal Village Bio-Energy Committee (VVBEC) comprising of 10 members representing Commercial electricity user (1), Farmer (1), Women SHG members (3), Laborers (2), Sarpanch (1), NGO (1) and ICRISAT representative (1) has been constitutionalized. The value chain approach will be adopted where the producers will be the beneficiaries of the process value addition for their Jatropha seeds. This concept is being perfected and evaluated.

Now, with the support of GTZ and Kirloskar Engineering Pvt Ltd., we are operationalizing a value-chain model for extracting oil through decentralized electricity generation in the village. This model plantation of 300 ha in two villages has set a live example of how degraded lands can successfully be used for producing *Jatropha* and *Pongamia*, without sacrificing good quality land and food security, which is very critical. Results of the social, economic and environmental impacts from this novel, collective action model of required degraded lands, are discussed.

Special Project Funding:
NOVOD, GoI, GTZ, India

<div align="right">SP Wani, Ch Srinivasa Rao, TK Sreedevi and S Marimuthu</div>

Output target 2011 7.2.1 Monitoring and management of pesticide residues and impact of IPM established

Achievement of Output Target:
40%
Methods to quantify pesticide residues are standardized and one year results of samples from Adarsha watersheds, Kothapally are finalized. Further conformation with more number of samples covering more farmers is needed.

Activity 7.2.1.1 Capacity-building of NARES about the importance of toxic residues on their health and environment and monitoring them in various crops and eco-system

Participating countries:
India

Participating Partners:
ANGRAU, Hyderabad

Progress/Results:
Monitoring of insecticide residues in food crops (rice, maize, pigeonpea), cotton and vegetables (tomato, brinjal) and natural resources (soil and water) has been continued in Kothapally watershed during 2009. Out of 54 samples collected from food crops only two samples (soil sample from maize field and rice grain sample) were found contaminated with endosulfan (0.022 and 0.538 ppm). None of the samples collected from cotton fields showed insecticide residues during 2009. Out of 105 samples from tomato crop and soils, 17 samples had insecticide residues (below detectable level to 0.5 ppm) and out of 80 samples from brinjal fields, 20 samples had insecticide residues (0.01 to 0.7 ppm of monocrotophos, endosulfan and cypermethrin). Of 35 samples collected from tomato IPM fields, 3 were found contaminated with residues (0.001 to 0.002 ppm of monocrotophos, endosulfan and cypermethrin) and 4 samples out of 35 samples in non-IPM trials showed residues (0.008 to 0.01 ppm of cypermethrin). Similar trend was also observed in brinjal fields with three fields in IPM and six in non-IPM recorded with residues of monocrotophos, endosulfan and cypermethrin.

Special Project Funding:
SDTT and SRTT

GV Ranga Rao KL Sahrawat and SP Wani

Output target 2011 7.2.2 Impact of diversification with high-value crops assessed and documented in two countries

Achievement of Output Target:
50%

Activity 7.2.2.1 **Impact of integrated watershed interventions on water productivity at benchmark watersheds in semi-arid tropics of China**

Participating Countries:
India, China, Thailand and Vietnam

Participating Partners:
CAAS

Progress/Results:
Benchmark watersheds in China: The ADB supported project "Participatory Watershed Management for Reducing Poverty and Land Degradation in SAT Asia" was implemented in a consortium mode by ICRISAT and Chinese consortium partners; at two benchmark watersheds in China – Lucheba watershed in Guizhou province and Xaixiocun watershed in Yunnan province.

Lucheba watershed: Lucheba watershed located in the central region of Guizhou province, about 75 km away from capital Guiyang belongs to Tianlong Township of Pingba County. Altitude is 1200–1400m above mean sea level with average rainfall of 1284 mm. The population is 1350 with 365 households dispersed in 11 villages (hamlets) with 6 farmers village groups. The total area of the watershed is 721 ha. Major crops are rice, corn, rape, soybean, sunflower, kidney bean and vegetables like cabbage, tomato, pumpkin, chillies, eggplant, etc. Rice-rape, corn-rape, are some of the major cropping systems. Farmers apply sufficient quantities of FYM and chemical fertilizers for their crops. Several soil, water, crop and nutrient management interventions were implemented in the watershed.

Xiaoxincun watershed: Xiaxincun watershed, a village of Jinlei group. The Julin town is situated in the mid-north of Yunnan province, belonging to Yuanmou county. The Chuxiong Yi tribe is one of the 25 ethnic groups in Yunnan province. It is a typical hot-arid valley area with mild slope of hills with the altitude of 1086–1100 m above sea level near the Longchuanjiang River. It is representative of the Xerothermic valley region in China with hot wet summer and warm dry winter seasonal climate. The average rainfall (1956–1990) was 612 mm but recent average (1997–2002) is 781 mm. The total land area is 186.7 ha. Due to erosion many gullies have developed accounting for 71.5 % of the total area. The total population in the watershed is 316, consisting 194 male and 112 female. There are 84 households. The major constraints for crop production are lack of water due to low and erratic rainfall with frequent droughts. Soil erosion is equally a major problem as the thin natural soil resource is already dwindling. Farmers in the watershed are resource poor and their per capita income was less than US$ 17 compared to US$ 45 average per capita of the country. Several soil, water, crop, nutrient and pest management interventions implemented during the project.

Impacts of various interventions on water productivity: Rainwater use efficiency (RWUE) of vegetable and watermelon crops during pre-project was increased by 13% in vegetables and 16% in watermelon (Table 1).

Table 1. Rainwater use efficiency of vegetable crops and watermelon during pre- and post-project periods at Lucheba watershed, China.

Crops	Pre-project period (2003)		Post-project period (2005)		Increase (%)
	Crop yield (t ha⁻¹)	RWUE* (kg mm⁻¹)	Crop yield (t ha⁻¹)	RWUE* (kg mm⁻¹)	
Vegetables	**36.9**	**28.8**	**41.9**	**32.6**	**13**
Watermelon	**11.3**	**8.8**	**29.3**	**22.8**	**161**

* RWUE (kg mm⁻¹) = Crop yield (kg ha⁻¹) / mean annual rainfall (mm)

The net yield advantage and net monetary benefit per unit water conserved for watermelon and vegetables were 287.3 and 78.7 kg mm⁻¹ ha⁻¹ respectively. Where as net monetary benefits were in the order of vegetables and watermelon with 147.1 and 83.4 RMB mm⁻¹ ha⁻¹ (1 US$ = 7 RMB) respectively, which reflected a similar trend of net monetary advantage per unit area with 9253 and 5246 RMB ha⁻¹ respectively

over two years due to availability of water during critical stages required by these crops attributed to the water harvesting tanks facilitated the supplementary application of water (Table 2). The increase in the net returns of vegetable per unit of water per unit area was about 3.5 times in post-project period compared to pre-project period.

Table 2. Effect of watershed interventions on crop yields per unit of water conserved at Lucheba watershed, China.

Crops	Net yield advantage (kg ha^{-1})	Yield advantage per unit of water conserved* (kg mm^{-1} ha^{-1})	Net monetary advantage [#] (RMB ha^{-1})	Net monetary advantage per unit of water conserved [#] (RMB mm^{-1} ha^{-1})
Vegetables	5000	78.7	9253	147.1
Watermelon	18100	287.3	5246	83.4

* Yield advantage per unit of water conserved (kg mm^{-1} ha^{-1})= Net increase in yield (kg ha^{-1}) / water conserved (mm)
[#] Net monetary advantage per unit of water conserved (RMB mm^{-1} ha^{-1})=Net benefit (RMB ha^{-1}) / water conserved (mm)

The benefit cost ratios for vegetables and watermelon are shown in Table 3. Similar trend of benefit cost ratios are recorded during pre- and post project periods for vegetables followed by watermelon. The B:C ratios during pre-project for vegetables and watermelon were 1.4, 0.5 respectively and during post-project were 1.8, 0.6 respectively. Higher B:C ratios were observed with vegetables than watermelon during both the pre- and post project periods.

Table 3. Effect of watershed interventions on the B:C ratio at Lucheba watershed, China.

Crops	Pre-project			Post-project		
	Yield (t ha^{-1})	Net income (RMB ha^{-1})	B:C	Yield (t ha^{-1})	Net income (RMB ha^{-1})	B:C
Vegetables	36.9	358	1.4	41.9	537	1.8
Watermelon	11.3	159	0.5	29.3	240	0.6

SP Wani, R Sudi, P Pathak, TK Sreedevi , Vamsidhar Reddy, Yin Dixin and Zhong Li

Activity 7.2.2.2 Evaluation of biological nitrification inhibition, productivity and nitrogen uptake of sorghum and sweet sorghum in response to nitrogen fertilizer.

Achievement of Output Target:
Over 50% was achieved
The methods to quantify BNI activity are standardized as well as to quantify N_2O emissions. Response trials with sweet sorghum lines and N levels need to be continued for two more years.

Participating Countries:
India and Japan

Participating Partners:
ICRISAT and Japan International Research Center for Agricultural Sciences, Japan

Progress/Results:
Sorghum (PKV 801, NTJ 2, CSH 16 and HTJH 3201) and sweet sorghum (CSH 22SS) were cultivated in the experimental fields (Alfisols and Vertisols). Soil samples were collected around the root of the crops and the nitrification activity were compared among soil samples by the soil incubation test.

Field experiments were conducted in the rainy and the post rainy season in 2009 (in Alfisols). Sweet sorghum was cultivated with six different N doses. Although there was no significant difference in stalk fresh weight and brix, juice volume differed significantly between treatments, resulting in the significantly higher sugar yield in 90N and 150N than in 0N and 30N. Severe lodging in 150N treatment made harvesting difficult. Grain dry weight was significantly higher in 90N and 150N than in 0N and 30N and total dry weight tended to be higher in high nitrogen input treatments.

Takeshi Watanabe, SP Wani and S Marimuthu

Output 7.3: Environmental impacts of livestock intensification reduced during droughts and the dry season by developing and promoting alternative feed and fodder strategies in crop-livestock systems with associated capacity building
Moved to Project- 9

Output 7.4: Opportunities for the market exploitation of biodiesel tree products by the poor promoted with associated capacity building

Output target 2009 7.4.1 Identified superior accessions of Jatropha in terms of test weight and oil content are inducted for field evaluation

Achievement of Output Target:
80%
Based on last four years results superior accessions of Jatropha are identified and included in evaluation trials in India. Similar work in Mali is already initiated and accessions performance in field evaluation is in progress.

Activity 7.4.1.1 Assessing Variability and Divergence of *Jatropha curcas* Linn. Germplasm under Ex-situ Conditions

Participating Countries:
India, Mali, Niger

Participating Partners:
READ, CRIDA, ANGRAU, ICRISAT, University of Hohenheim, IER, Mali, AMEDD/GERES, National Bureau of Plant Genetic Resources (NBPGR), India, CSOs and CBOs

Progress/Results:
Understanding the existing variability for different characters amongst the seed samples of *Jatropha curcas* is very important to harness the potential through crop improvement. The NBPGR along with the consortium partners of the GoAP project have collected number of seed samples of *Jatropha*. Further, these samples were grown in fields at ICRISAT to assess the variability for other agronomic characters as well as to confirm the genetic variability for oil content and seed weight when grown under uniform environment. Among this 124 an evaluation of 99 genotypes of *Jatropha curcas* was carried out to assess variability and character association and to identify diverse genotypes with superior growth and seed traits. Variability studies revealed that, 42 accessions performed better in terms of above average for volume index (33935 cm^3), among the accessions evaluated in the field, indicating the vigor of the plants. Similarly, 54 and 63 accessions recorded more than the average for 100 seed weight (52.7 g) and oil content (29.4 %) respectively. Frequency distribution for seed oil content of mother and progenies is presented in Table 2. Forty-four and 5 per cent of the genotypes have exhibited oil content in the range of 35.1 – 40 % in seeds of mother and progenies respectively (Table 1). A wide spread of variation was observed for Plant height (104.8 - 273.7 cm), Collar diameter (5.1 - 18.9 cm), number of branches (9.7 - 66.3), crown area (0.5 - 6.3 m^2), volume index (8055.8 - 85707.7 cm^3), seed length (11.6 - 19.3 mm), seed width (9.5 - 11.7 mm), seed thickness (7.6 - 11.0 mm), 100-seed weight (38.9 - 67.1 g), seeds oil content of mother plant (27.5 - 40.5) and progeny seeds (18.7 - 36.4). Genetic advance was considerably larger in the growth traits and seed oil content as compared to the seed characteristics. However, oil content from progeny seeds expressed 77.2 % of heritability with 21.9 genetic advance per cent of mean. Oil content of seeds from progeny plant showed positively significant correlation at both level with 100-seed weight ($r_g = 0.75$; $r_p = 0.42$) and only at genotypic level with seed thickness ($r_g = 0.24$). 100-seed weight expressed positive and significant correlation with collar diameter ($r_g = 0.32$), number of branches ($r_g = 0.29$), volume index ($r_g = 0.27$), seed length ($r_g = 0.31$), seed width ($r_g = 0.32$) and seed thickness ($r_g = 0.26$) only at genotypic level. The first five Principal Component (PCs) explained large portion (85.4 %) of the total variation. Clustering analysis resulted into three broad clusters. Genotypes in cluster – 3 had combination of desirable traits and can be directly selected for further improvement by breeding.

Table 1. Frequency distribution of 99 germplasm accessions of *J. curcas* for oil content of mother plant and progeny seed.

Traits	Range	No. of accessions
Seed oil % (mother plant)	< 20	-
	20.1 – 25	-
	25.1 – 30	4
	30.1 – 35	50
	35.1 – 40	44
	> 40	1
Seed oil (progeny)	< 20	1
	20.1 – 25	11
	25.1 – 30	42
	30.1 – 35	40
	35.1 – 40	5
	> 40	-

From the above study, identification of good genotype may be graded based on crown area, volume index and seed weight is advantageous. Since traits *viz.*, crown area, volume index and seed oil content are having high heritability and genetic advance, consideration may be given for further improvement by selection and breeding. Genotypes ICJC 06004, ICJC 06116, ICJC 06120, ICJC 06010 were found to be superior on the basis of volume index (76077 cm^3), 100-seed weight (67.1 g), progeny seed oil content (36.4 %), crown area (6.3 m^2) respectively, hence these genotypes may be given importance for massive afforestation programme.

Along with the vegetative growth parameters different plants varied for the flowering characteristics such as number of flowering branches varied from 1 to 7.2 per plant with mean of 3 and number of inflorences per plant varied from 1 to 8.8 with a mean of 3.1 per plant amongst different seed samples. Most importantly large variation for female to male flower ratios (3.5 to 16.5) was also observed amongst different samples with a mean of 1:10 during the first flowering season after planting. Many plants yielded fruits and variation for the yield determining characters such as number of female flowers (2 to 45), pod bunches per plant (1 to 7), number of pods per plant (3 to 90), and seed yield (28 to 270 g) was observed. Seed oil content varied from 27.4 to 40.6 per cent amongst different accessions with a mean oil content of 34.3 per cent (Table 1). During the fourth year seed yield of different plants from *Jatropha curcas* accessions varied a lot with a maximum seed yield of 1.4 to 1.6 kg per plant in a block evaluation trial with spacing of 3 x 2 m reaching to 2.7 t ha^{-1}.

BN Divakara, SP Wani and HD Upadhyaya

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Grouping of 99 *Jatropha curcas* genotypes based on scores
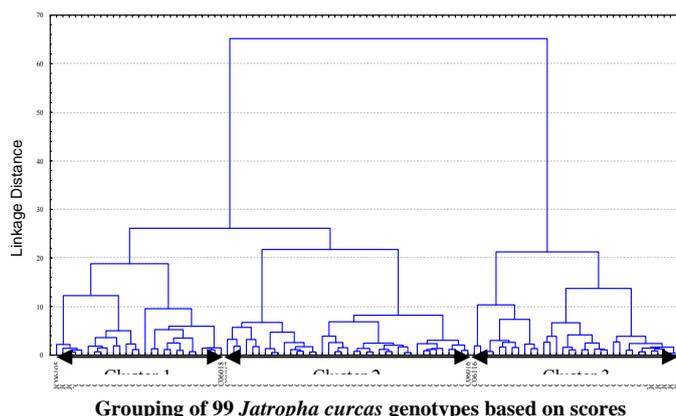
Activity 7.4.1.2 Assessment of Variability in *Jatropha curcas* Accessions Using Molecular Markers

Participating Countries:
India

Participating Partners:
READ, CRIDA, ANGRAU, ICRISAT, University of Hohenheim, National Bureau of Plant Genetic Resources (NBPGR), India, CSOs and CBOs

Progress/Results:
Amplified fragment length polymorphism (AFLP) was employed to assess the diversity in the elite germplasm collection of *J. curcas,* which has gained tremendous significance as a biofuel plant in India and many other countries recently. Forty-eight accessions from six different states of India, were used with seven.

AFLP primer combinations that generated a total of 770 fragments with an average of 110 fragments per primer combination. A total of 680 (88%) fragments showed polymorphism in the germplasm analyzed, of which 59 (8.7%) fragments were unique (accession specific) and 108 (15.9%) fragments were rare (present in less than 10% accessions). In order to assess the discriminatory power of seven primer combinations used, a variety of marker attributes like polymorphism information content (PIC), marker index (MI) and resolving power (RP) values were calculated. Although, the PIC values ranged from 0.20 (E-ACA / M-CAA) to 0.34 (E-ACT / M-CTT) with an average of 0.26 per primer combination and the MI values were observed in the range of 7.05 (E-ACA / M-CAA) to 9.92 (E-AGC / M-CTA) with an average of 8.70 per primer combination, the RP was recognized the real attribute for AFLP to determine the discriminatory power of the primer combination. The RP values for different primer combinations varied from 3.87 (E-ACA / M-CAT) to 7.85 (E-AGG / M-CTA) with an average of 6.14. Genotyping data obtained for all 680 polymorphic fragments were used to group the accessions analysed using the UPGMA- phenogram and principal component analysis (PCA). Majority of clusters/grouped obtained in phenogram and PCA contained accessions as per geographical locations. In general, accessions coming from Andhra Pradesh were found diverse as these were scattered in different groups, showed occurrence of higher number of unique/rare fragments and had greater variation in percentage oil content. Molecular diversity estimated in the present study combined with the datasets on other morphological/agronomic traits will be very useful for selecting the appropriate accessions for plant improvement through conventional as well as molecular breeding approaches.

Special Project Funding:
IFAD, GoAP, D1 Oils Fuel Crops

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T Leela, SP Wani, S Kannan, N Beerelli, TK Sreedevi,
DA Hoisington, P Devi and RK Varshne*y*

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Activity 7.4.1.3 Collection and evaluation of *Jatropha* accessions for seed production and seed oil content in Niger, Mali

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES and CBOs

Special Project Funding:

Progress/Results: IFAD
One of the important task of year 2009 work plan was to collect seeds from various regions of Mali and if possible from other countries in West Africa.
- Seed collection was organized in Mali by the IER project leader Dr Modibo Sidibe in November 2009. He targeted regions of Mali where Jatropha is grown. This seed collection trip resulted in a collection of 17 accessions. Seeds will be formally transferred to ICRISAT not later than end of February for storage in the gene bank. In addition to the collections conducted in Mali three (3) accessions were obtained from the National tree seed centre of Burkina Faso (West Africa).
- These collections will be enlarged with new collections from Mexico and East Africa through partnership with the University of Copenhaguen National research institute of Mexico and ICRAF. We are expecting to receive from these partners 23 more collections.

The full list of accession and site data are available in the project annual report.

- Three years (2007-2009) data on seed production were analyzed (ANOVA) to identify best accessions among the 16 evaluated at ICRISAT Sadore station. Pooled data for the 3 years showed significant difference between the accessions (P= 0.036). .The best accessions are BAAS38, Guinea Bissau and Mali (Kita) with respectively average annual yield over the 3 years of 324.1g, 321.1 g. And 321.2 g per plant. The lowest yield was performed by Las pilas a Mexican accession with an average yield over the 3 years of 64.8 g.
- Results from regression analysis indicate that production of individual trees in one year is correlated with the production of the same trees the following year: R^2 =0.70 for year one (Y1) and year two (Y2) and for Y2 and Y3 R^2 = 0.13.
- Evaluation of morphological characters indicates that leaves and flowers characters (leaf petiole, leaf limb length and width, inflorescence length and flower peduncle length) can be used to discriminate Jatropha accessions.

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.4 Jatropha accessions performances in two different eco-zone in West Africa

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES, and CBOs

Progress/Results**:**
The accessions planted in 2008 at Niamey and Samanko have been assessed for growth and survival performance. Niamey and Samanko represent different ecological conditions. The Sadore (Niger) site is characterized by low rainfall (400-500 mm) and poor sandy soil while Samanko (Mali) is characterized by an average rainfall of 1000 mm and a relatively rich loamy soil. In total 16 accessions were planted at Sadore (ICRISAT station in Niger) and 18 at ICRISAT station (Mali). Growth parameters such as stem diameter, height, number of branches and survival rate show better performance in Samanko (ICRISAT Mali station) conditions. Plantation established at Samanko (Mali) gave an average seed yield of 246 g per tree one year after plantation compare to 13.8 g. at Sadore. Plant survival 16 months after transplanting was 83.3% at Samanko compare to 47.9% at Sadore. Plant height was also higher at Samanko with an average of 141.4 cm compared to the 97.2 cm as average height at Sadore. These results clearly show that plants performed better at Samanko than Sadore. The low survival rate at Sadore can be interpreted as poor adaptation of Jatropha in Sadore conditions.

Special Project Funding:
IFAD

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.5 Assessing variability *Pongamia pinnata* Germplasm under *Ex-situ* Conditions

Participating Countries:
India

Participating Partners:
READ, CRIDA, ANGRAU, ICRISAT, University of Hohenheim, National Bureau of Plant Genetic Resources (NBPGR), India, CSOs and CBOs

Progress/Results:
Similar evaluation of Pongamia accessions was also done and variation for plant growth parameters is recorded. The plant height varied from 135 to 380 cm with a mean of 243 cm, number of branches varied from 3 to 25 with a mean of 13, stem girth varied from 10 to 40 cm with a mean of 54 cm, North-South spread varied from 40 to 300 cm with a mean of 134 cm, East-West spread of the trees varied from 45 to 260 cm with average of 127 cm. During the fourth year although sparse flowering was recorded no significant fruit yield was recorded from the plants grown from the seeds.

Special Project Funding:
GoAP and GoI

BN Divakara and SP Wani

Output target 2009 7.4.2 Water requirement studies is undertaken on Jatropha to establish water balance in catchment's areas when Jatropha is planted

Achievement of Output Target:
50%
The Jatropha crop is not fully grown for accurate estimates of its water requirement. This work needs to be repeated for a few more years to know its water needs with changing ground cover.

Participating Countries:
India

Participating Partners:
READ, CRIDA, ANGRAU, ICRISAT, University of Hohenheim, National Bureau of Plant Genetic Resources (NBPGR), India, CSOs and CBOs

Progress/Results:
Soil moisture dynamics is monitored in the Jatropha plantation at ICRISAT since November 2005 to estimate its water requirement using water balance approach. The results have indicated that during April to June, ET requirements are high due to atmospheric demands as well as the vegetative stage of plantation. However, this is the period in which the actual availability with respect to demand is low. During July to October, soil moisture status is sufficient to satisfy much of the ET requirements; this period coincides with flowering and fruit set stage. Jatropha has used about 75 to 90% of the rainfall received in the past three years; lower percentage utilization occurred when the rainfall

distribution was erratic, though the rainfall amount was high. In the year 2008, rainfall till November was 1103 mm, however, total rainfall during June and July was only 190 mm compared to the normal of 305 mm. August rainfall was 382 mm compared to the normal of 220 mm. There were 8 days in the year 2008 with a rainfall of more than 50 mm and long periods of dry spells occurred in June and July. The total ET use by Jatropha in the year 2008 till November was 820 mm, the highest in the last three years. If the rainfall distribution was good, Jatropha could have used even more water. Study indicates that contrary to the belief that Jatropha needs less water, under favorable soil moisture conditions, Jatropha could use large amounts of water for luxurious growth and high yield. These studies are continuing at the research farm to assess the water requirements of Jatropha as the plantations mature and become older.

Kesava Rao, Piara Singh and SP Wani

Output Target 2010 7.4.1 Proof of concept that biodiesel trees are an economically and socially viable product for very poor and landless communities when granted usufruct rights on low quality non-titled land

Achievement of Output Target:
70%
Large scale plantation of 300 ha is four year old now. The CBOs are involved in generating energy using straight oil as commercial venture. The simulated economic model results will be validated with actual results. Social aspects are being studied.

Activity 7.4.1.1 Jatropha fuel from India's wastelands: A financial analysis of different Jatropha production scenarios linked to possible crude oil price developments.

Participating Countries:
India

Participating Partners:
READ, CRIDA, ANGRAU, ICRISAT, University of Hohenheim, National Bureau of Plant Genetic Resources (NBPGR), India, CSOs and CBOs

Progress/Results:
India's increasing energy consumption motivates the search for and the development of alternative energy sources. This research investigates the potential of Indian agro fuel; especially Jatropha-based fuel production on wastelands as alternative to fossil fuel. Jatropha's potential can be utilized by farmers to reclaim up to 20 million ha of the 55 million ha of wastelands in India thus expanding their income potential and reducing the environmental impact of economic development. We used a value chain approach to link the price of crude oil with that for Jatropha seeds. This was done via supplementing fossil diesel with Jatropha fuel - Jatropha pure plant oil and Jatropha methyl ester. We further applied financial analysis to three different Jatropha production scenarios using the derived maximum price for Jatropha seeds. Our focus was on the range of crude oil prices and interest rates at which Jatropha seed production becomes an economically viable investment as measured according to the net present value criterion. We found that at crude oil prices above US$ 75 per barrel (low cost scenario JPPO, interest rate 6%), Jatropha fuel production on India's wasteland starts to be economically viable. We conclude that both JME and JPPO have potential to serve as renewable energy source. The findings can serve the Indian state and federal governments to further develop appropriate political and economical framework conditions for the future diffusion of Jatropha fuel production in India.

Martin Grass, Manfred Zeller, SP Wani and TK Sreedevi

Activity 7.4.1.2 Survey to identify prospective seed producers of *Jatropha* in Mali

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES, and CBOs

Progress/Results:
The survey was carried out in the Koulikoro, Mande, Siby and Garalo areas to identify the prospective seed producers of *Jatropha.* The survey showed that producers are largely apprehensive of the profits they can get from various recommended interventions for *Jatropha* production. The major constraints are shortage of labor, complexity of operations and coincidence of the operations with other farm works. These constraints prevent farmers to undertake *Jatropha* cultivation. However, this survey identified 1017 producers in 12 cooperatives who received guidance of the local cooperative trade union to supply crude oil to the Mali Biocarburant company. The survey established the functional relationship among producers, cooperatives, the union and the Mali Biocarburant. Currently total area under *Jatropha* cultivation is 2034 ha and it is expected to expand to 5000 ha by 2012. It is expected to produce 1890 liters of oil per ha per year. Total oil production is estimated to be 9460000 liters /year and the number of producers could exceed 2000 farmers. The NGOs are sensitizing and training the producers for growing *Jatropha* in the identified three areas and the potential buyers of *Jatropha* oil have been identified.

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.3 Jatropha and Pongamia Rainfed Plantations on Wastelands in India for Improved Livelihoods and Protecting Environment

Participating Countries:
India

Progress/Results:
Results from literature also suggest that when Jatropha is grown on good quality lands, with irrigation and intercropping with baby corn, it is not economically superior to the sole cultivation of baby corn. In order to improve livelihoods of the rural poor by providing opportunities for additional income from Jatropha and Pongamia plantations, ICRISAT in partnership with Civil Society Organizations (CSOs) and Community-Based Organizations (CBOs) has developed a model to rehabilitate degraded common lands in a village. Three hundred ha of Jatropha plantation, which is three years old, has started producing yield. The grain yield from the third year onwards was 100 kg per ha and was expected to reach up to 1000 kg per ha by the sixth year. Growing intercrops on areas where good soil existed provided additional income for the farmers. The Jatropha and Pongamia plantations on waste lands have not only created employment in the rural areas but also provided additional sources of income through usufruct rights, by selling Jatropha seeds. Other impacts in terms of social capital development, building of institutions in the villages, improving soil health through recycling of organic matter and enhanced soil water conservation measures, reduced soil erosion and land degradation were also recorded. With the unique institutional mechanisms adopted in this model for development of CPRs through collective action, landless people were organized into self-help groups and took up labour work in the development of degraded common property resources, such as soil and water conservation measures, supported by the project. The District administration of the Government of Andhra Pradesh gave them usufruct rights over the plantation for harvesting the produce. Farmers are growing good quality grass and supporting their livestock and feed requirements from grass grown in-between the rows of plantations.

TK Sreedevi, SP Wani, CH Srinivasa Rao,
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Activity 7.4.1.4 Rhizosphere Microbiology of *Jatropha* and *Pongamia* Plants

Progress/Results:
Soil samples (rhizosphere and non rhizosphere) from four different locations (ICRISAT campus, Velchal, Siddhapur, Kothalapur) all in Andhra Pradesh, India were studied for microbial counts, microbial biomass, and dehydrogenase enzyme activity in the soil samples. The rhizosphere soil in locations planted with *Jatropha* and *Pongamia* recorded high populations of bacteria, fungi, actinomycetes as well as dehydrogenase activity (Figure 3a, 3b, 4a, 4b). The values of soil respiration, microbial biomass N, C and mineral N were high when compared with non-rhizosphere soil samples (Figure 3a, 3b, 4a, 4b). High microbial population in rhizosphere soil indicates increase soil biological activity, which was also observed with increased microbial biomass C and N. Number of bacteria and actinomycetes in the rhizosphere soils of *Jatropha* were more by 40 and 50% respectively than from the non rhizosphere soil samples. Numbers of fungi in the rhizosphere soil samples were more by two folds than the non-rhizosphere soil samples. Similar results were observed for higher number of bacteria, fungi and actinomycetes in rhizosphere soil samples of *Pongamia* than the non-rhizosphere soil samples also from two locations (Figure 4a, 4b).

The highest dehydrogenase activity was found in rhizosphere soils planted with *Jatropha* and *Pongamia.* The high values of microbial C and N in the rhizosphere soil indicated stimulation of biological activity in soil due to rhizosphere effects. *Jatropha* and *Pongamia* plants grow at different field conditions. This study shows that plantation of *Jatropha* and *Pongamia* stimulated soil microbial populations, which in turn recorded high soil biological activity as well as enzymatic activity due to rhizosphere activity. Although, *Jatropha* and *Pongamia* plants are Non-edible for human beings as well as animals, microbes were not adversely affected but were stimulated due to rhizosphere effect of *Jatropha* and *Pongamia.*
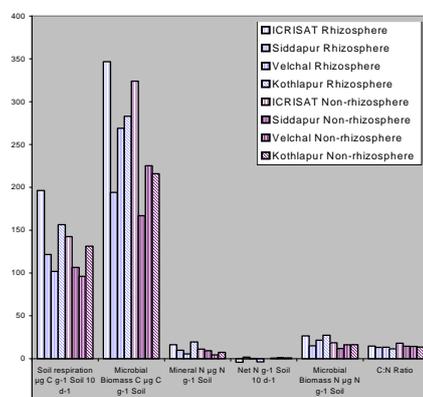
Figure 3a. Mean of Microbial parameters, Enzyme activities of rhizosphere and non rhizosphere soils planted with Jatropha at different locations in Andhra Pradesh, India
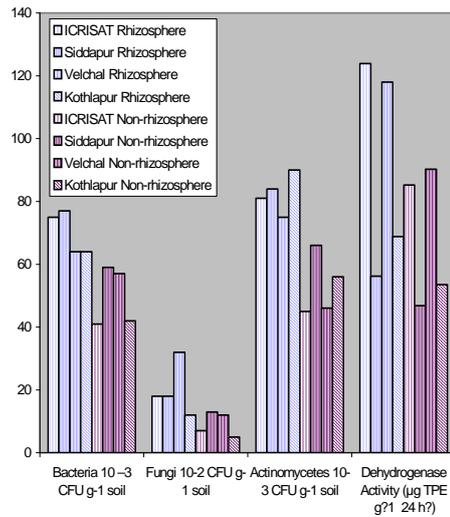
Figure 3b. Mean of Biological activities of rhizosphere and non rhizosphere soils planted with Jatropha at different locations in Andhra Pradesh, India
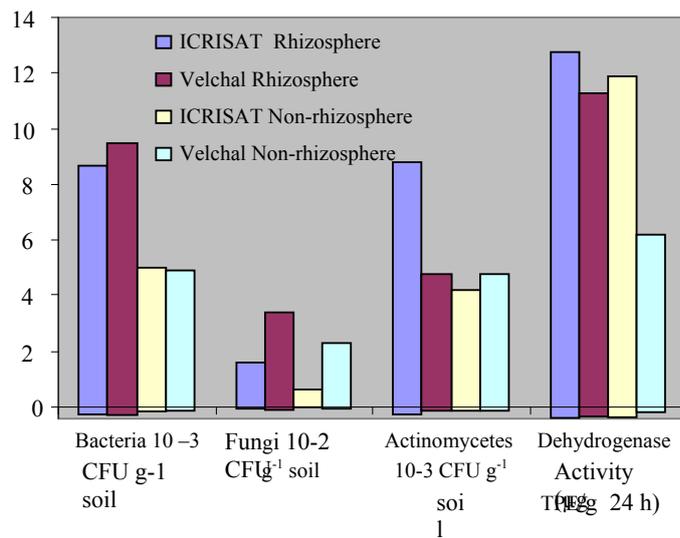

Figure 4a Mean of Microbial parameters, Enzyme activities of rhizosphere and non rhizosphere soils planted with Pongamia at different locations in Andhra Pradesh, India


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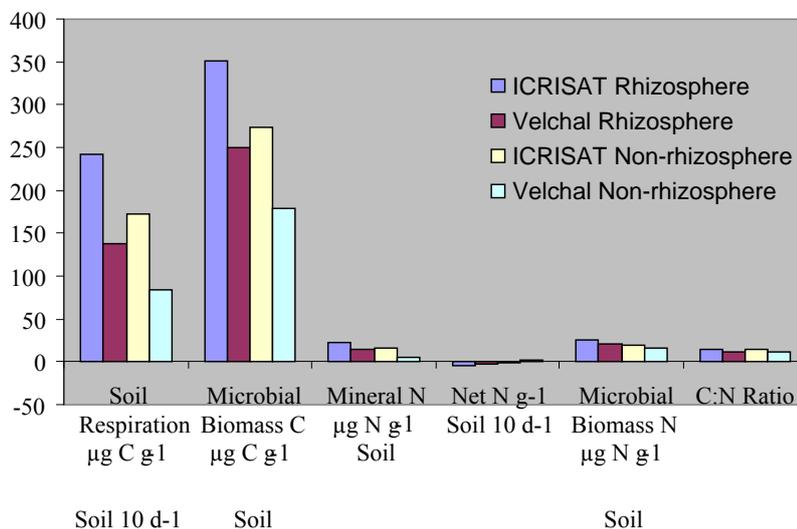
Figure 4b. Mean of Biological activities of rhizosphere and non rhizosphere soils planted with Pongamia at different locations in Andhra Pradesh,

SP Wani, TK Sreedevi and C Vineela

Output Target 2011 7.4.1 Recommendations for suitable agronomic practices for the block plantation of trees with potential for use as sources of biodiesel

Achievement of Output Target:
50%
As the plantations are attaining production potential, the effects of different agronomic practices on *Jatropha* yields will be available. The results available till present show impact on plant growth and impact on seed yields need to be studied.

Activity 7.4.1.1 Effect of spacing (planting density) on vegetative and reproductive growth and development, yield and oil parameters of *Jatropha curcas*

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
Experiments at Medak (ICRISAT campus), Kurnool and Nalgonda districts of Andhra Pradesh evaluated the performance of E1 *Jatropha* accession under different spacing. Experimental site (marginal land not used for growing crops) in Kurnool district was identified at Cherukucherla village in Midthur mandal with the help of Weaker Communities Upliftment Service Society (WCUSS)an NGO and village Panchayat at Cherukucherla Soil sampling was done at 0-30 and 30-90 cm depth to characterize soil physical and chemical properties. The field layout was super imposed for establishing both *Jatropha* agronomy and progeny trials. The design of the experiment is randomized block design with three replications. The pits of 45 x 45 x 45 cm, were made as per the layout and filled with 2 kgs of farm yard manure (FYM). The seedlings were planted on 19th September, 2008 along with application of 50 g of Di ammonium phosphate (DAP) per plant. After cultivation, measures like weeding and basin making were carried out soon after the establishment of seedlings. The growth parameters like plant height and number of branches per plant are recorded at bi monthly intervals. The remaining trials at ICRISAT campus and Nalgonda district were also established during the 2009 monsoon season. Mean plant height was recorded at 6 months after planting under different spacing treatments. Among all the spacing treatments, spacing 1 x 1m recorded maximum mean height of 39.8 ± 6.6 cm, whereas at spacing 3 x 3m recorded minimum mean height of 32.0 ± 5.3 cm. There is no clear trend in growth habit as there is nil or minimum competition between the plants at the early stage.

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Activity 7.4.1.2 Product placement trial

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
To evaluate the agronomic performance of D1 **Oils Fuel Crops** materials and local accessions, product placement trials with 10 *Jatropha* accessions were established both in ICRISAT campus and Cherukucherla village at Kurnool following randomized block design with four replications constituting nine plants per accession per replication. Agronomic practices were followed as mentioned in spacing trials. Mean performance of selected accessions of *J. curcas* for height under different locations are presented in Tables 2 and 3. In general, all the accessions performed better in Cherukucherla location compared to ICRISAT location for height at 6 months after planting. Among all the accessions, D5 recorded highest for height at ICRISAT (15.09±6.99 cm) and Cherukucherla (23.56±6.02 cm).

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Activity 7.4.1.3 Nutrient Content of Fallen Leaves, Pruned Branches, Seeds and Seed cake of Jatropha

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
As the *Jatropha* has to be grown on degraded lands as per the policy of the GoI, it is critical to assess the nutrient demand of the plants and assess return of plant nutrients as well as carbon to the soil that can contribute in improving soil health. *Jatropha* plants have a unique mechanism of drought tolerance by dropping all it's leaves during the moisture stress and minimizing its water requirement. This characteristic of *Jatropha* comes handy for rehabilitating the degraded lands which are severely depleted in organic carbon and as a result have low water holding capacity.

Using the different plant parts samples from the various treatments at ICRISAT research experiments we attempted to draw general principles, which can help in improving the management of *Jatropha* plantations. The nutrient content analysis of different plant parts' results presented in the Table 2 revealed that highest nitrogen content of 49500 mg kg^{-1} was recorded in seed cake followed by 22800 mg N in seeds, 16100 mg N in pruned shoots and 9500 mg N per kg fallen leaves. Phosphorus content in plant parts varied from 700 mg P in leaves to 4800 mg per kg in seeds (Table 2). Seed were rich in nitrogen content with 22800 mg N per kg followed by potassium (8100 mg kg^{-1}), phosphorus (4800 mg kg^{-1}), sulphur (1400 mg kg^{-1}), zinc (17.8 mg kg^{-1}) and boron (15 mg kg^{-1}). Fallen leaves were rich in potassium (10000 mg kg^{-1}), followed by nitrogen (9500 mg kg^{-1}), sulphur (941 mg kg^{-1}). Nitrogen and sulphur contents amongst the plant parts were highest in seeds, followed by stem and least in leaves. Potassium content was highest in pruned shoots, followed by leaves and least in seeds. Amongst the plant parts boron content was highest in leaves followed by seeds and least in pruned shoots (Table 2).

The mass of fallen leaves and nutrient content in case of *Jatropha* plantations varied with the age (Table 3) as well as with the fertility treatment. Leaf fall in case of three years old plants was 2.6 folds more than incase of one-year plants (1451 vs. 552 g plant^{-1}), however, nitrogen concentration in fallen leaves was 32 per cent higher (11400vs.8600 mg kg^{-1}) in case of leaves from one-year plants that of the leaves from three-year plants.

Table 2. Nutrient content (mg kg^{-1}) in fallen leaves, shools, seeds and seed cake of *Jatropha Curcas*, ICRISAT, Patancheru.

	N	P	K	S	B	Zn
Shools	16100	2400	23300	1289	11.2	43.6
Leaves	9500	700	10000	941	33.8	23.3
Seeds	22200	4800	8100	1400	15.0	17.8
Seed Cake	49500	4400	8900	2114	18.1	32.2

Table 3. Quantity and nutrient content and amounts of nutrients returned through fallen leaves in *Jatropha* plantation soil of different ages, ICRISAT, Patancheru.

Age of the plant	Fertilizer dose	Dry leaf (g plant^{-1})	% N	% P	% K	Nutrient recycling by leaf litter (kg ha^{-1})		
						N	P	K
1 year old					1.10	15.7	0.8	15.2
3 years old	100g Urea and 38g SSP	1451.1	0.86	0.08	0.95	20.8	2.0	23.0

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Activity 7.4.1.4 Nutrient Recycling and Organic Carbon Addition through Fallen Leaves

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
In case of *Jatropha* plants fertilized with 90 kg N ha^{-1} nutrient recycled were calculated using leaf mass data and different nutrient concentrations in the fallen leaves. Three major plant nutrients viz; nitrogen, phosphorus and potassium recycled were quantified. One-year plantation with 3x2 m spacing with 1666 plants per ha returned 15.7 kg N, 0.8 kg P, and 15.2 kg K per ha. Three-years old plantation recycled 20.8 kg N, 2 kg P and 23 kg K per ha through fallen leaves. Recycling of nutrients through fallen leaves has very important role in sustaining the productivity of *Jatropha* plantations as nutrients from deeper soil depth used by the plants will be recycled through decomposition in top soil layer. Secondly in addition to the nutrients recycled within the soil-plant system, soils will be enriched with valuable organic carbon fixed by the plants and added to the soil through fallen leaves. Considering that 2.5 t fallen leaves ha^{-1} containing 40% organic carbon additions to the soil works out to be around 1000 kg per ha in case of three-years old plantation. Addition of 1000 kg organic carbon fixed from the atmosphere not only reduces the concentration of CO_2 in the atmosphere but will increase system's productivity through improved soil organic carbon addition which is critically needed in the tropics. Tropical soils are poor in their organic carbon content (Wani et al. 2003, Sahrawat et al. 2008) and through improved cropping systems and improved management options good potential for carbon sequestration exists in the semi arid tropical systems. Pigeon pea-based systems in the SAT fixed 350 kg C per ha in Vertisols up to 150 cm depth largely through fallen leaves and root mass left in the soil. Carbon sequestration could help improving rural livelihoods in the SAT through harnessing the potential of tropical agricultural systems by adoption of improved soil, water, nutrient, and crop management options (Wani et al. 2007).

Under tropical conditions return of 1000 kg C per ha per year is quite substantial through *Jatropha* plantations and this additional environmental benefit in addition to renewable energy needs to be considered. There is an urgent need to assess the potential of biodiesel plantations in the tropical countries for total carbon sequestration including in the soil as well as through C replacement of fossil fuel-based diesel. Carbon sequestration is one of the most important environmental services provided through forests and agricultural systems in the tropics. At ICRISAT our team is already addressing systematically this issue of C sequestration in case of *Jatropha* and *Pongamia* plantations under different systems. Our studies on *Pongamia* showed that this plant has a very good potential for C sequestration along with it's inherent ability to fix atmospheric nitrogen through biological nitrogen fixation.

Table 4. Nutrient uptake through seeds (kg ha^{-1}) at different levels of seed production.

Nutrient	Seed yield (t ha^{-1})				
	1	2	3	4	5
N	22.2	44.4	66.6	88.8	111
P	4.8	9.6	14.4	19.2	24
K	8.1	16.2	24.3	32.4	40.5
S	1.4	2.8	4.2	5.6	7
B	0.015	0.03	0.045	0.06	0.075
Zn	1.7	3.4	5.1	6.8	8.5

Activity 7.4.1.5 Nutrients Requirement for Targeted *Jatropha S*eed *Y*ield Based on Nutrient *B*udgeting

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
Detailed nutrient concentrations in different plant parts along with amount of plant materials returned to soil and seeds removed from the fields for the purpose of oil extraction enables us to look at the nutrient requirements to achieve the targeted crop yields. Our results showed that one ton seeds of *Jatropha* remove 22 kg N, 5 kg P and 8 kg K per ha (Table 4). Average productivity of 3 t seeds ha^{-1} will remove 66 kg N, 15 kg P and 24 kg K per year per ha. In order to sustain the productivity of the field at this level we need to return equivalent quantities of N, P and K in a simple arithmetic terms (Table 4). However, nutrient availability in soil from different sources of nutrients varied significantly depending on the C:N ratio, biological activity along with soil moisture and temperature. For mineral fertilizers recovery of nutrients for example in case of N is about 40-45% where as from organic matter of wider C:N ratio such as fallen leaves with 40:1 C:N ratio N and other nutrient availability will be far less (<20 per cent)during first year of application. Leaf fall data and return of nutrients through leaf fall indicated that three-years plantation returned 21 kg N, 2 kg P and 23 kg K per ha. Applying the efficiency of release and uptake of N from the fallen leaf material it may able to provide about 5 kg N per ha at best. It means for achieving target yield of 3 t ha^{-1} seeds, one will need to meet the demand of additional 60 kg plant available N per ha and applying the basis of even 50% recovery from the chemical fertilizers one will need to apply about 120 kg N per ha. Similar will be the case for phosphorus which will need application of 14 kg P i.e. 38 kg P$_2$O$_5$ per ha. These studies clearly indicate that for sustainable *Jatropha* production at any level will definitely need application of plant nutrients in sufficient quantities. Through leaf fall and application of oil seed cake a byproduct after extraction of oil can meet the partial plant demand for the nutrients however, nutrients such as N and P will have to be supplied externally. Other nutrients such as K, Zn, B and S may not be needed to apply regularly as removal of these nutrients through seeds is quite less and return through leaf fall is considerable. However, detailed studies on nutrient release patterns from the fallen leaf material as well as oil seed cake are needed to arrive at the right nutrient dose applications to sustain seed yields.

Activity 7.4.1.6 Pongamia seed cake as a valuable source of plant nutrients for sustainable agriculture

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
Pongamia a multipurpose leguminous tree containing non-edible oil grows widely in India. Oil extracted from the seeds of Pongamia is used as energy source as well as in tanneries while the cake (a by-product after extracting oil) was found to be rich in all plant nutrients in general and nitrogen (4.28%) and sulphur (0.19%) in particular. Both nitrogen and sulphur were found to be deficient in 100% and 80% soil samples from farmers' fields in Powerguda village of Adilabad district, respectively. Use of Pongmia seed cake as a source of plant nutrients for maize, soybean and cotton was found beneficial in participatory research and development (PR&D) trials on farmers' fields. Further, application of critically deficient micronutrients such as zinc and boron and secondary nutrient sulphur increased crop yields by 16.7% and 19% in soybean and cotton, respectively. Additional B:C ratios of 5.03, 1.81 and 2.04 were obtained for soybean, maize and cotton, respectively with use of cake as a source of N, however it needed higher initial investment.

Activity 7.4.1.7 Intercropping with *Jatropha* and *Pongamia*

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
When *Jatropha* and *Pongamia* are grown on low quality arable lands. It is possible to grow intercrops which can provide additional income to the farmers. However, as indicated in the nutrient budgetary approach appropriate amendments with necessary requirements are must to ensure good crop productivity. At ICRISAT research center, where agronomic and different accessions evaluation trials of *Jatropha* and *Pongamia* are conducted we have evaluated the feasibility of growing different crops as intercrops with *Jatropha* and *Pongamia*. In these experiments we have observed that crops like sorghum, pearl millet, pigeonpea, soybean, mung bean, chickpea, sunflower and safflower can be successfully cultivated during rainy season and post-rainy season. Productivity of these crops in terms of grain yield varied from 0.29 t ha^{-1} in case of green gram to 1.5 t ha^{-1} in case of sorghum. Total economic value from additional income through grains and fodder from these crops varied from Rs. 5355/- to Rs. 20430/- per ha in case of *Jatropha* intercrops (Table 5) with *Pongamia* plantations pearl millet and pigeonpea have been successfully grown achieving productivity of 0.5 t ha^{-1} in case of pigeonpea and 1.1 t ha^{-1} in case of pearl millet grains. Total economic value from the additional income of intercrops in case of *Pongamia* intercrops systems is around Rs. 10700/- per ha (Table 5).

Table 5. Grain and fodder yield of different crops grown as intercrops with four years old *Jatropha* and *Pongamia* plantation, rainy season, 2008.

Biodiesel crop	Intercrop	Grain (t ha^{-1})	Grain value (Rs.)	Stalk (t ha^{-1})	Fodder value (Rs.)	Total economic value (Rs.)
Jatropha						
	Sorghum	1.50	9300	3.71	11130	20430
	Pearl millet	1.18	7080	2.07	4140	11220
	Pigeonpea	0.59	9381	2.07	2070	11451
	Soybean	0.51	5355	0.67	0	5355
	Mung bean	0.29	5046	1.36	0	5046
	Chickpea	1.01	16016	0.89	445	16461
	Sunflower	0.98	14798	2.85	0	14798
	Safflower	0.54	8910	2.33	0	8910
Pongamia						
	Pearl millet	1.14	6840	1.93	3860	10700
	Pigeonpea	0.57	9063	1.62	1620	10683

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Activity 7.4.1.8 Identification of best agronomic practices in Africa

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES, and CBOs

Progress/Results:
- On-farm experiment was established in collaboration with a local NGO (AMEDD/GERES) in July 2009 at Koutiala (Mali). Ten (10) different spacing of Jatropha intercropped with groundnut and sorghum are being tested using a complete randomized bloc design. Tree/crop Interactions will be assessed annually starting 2010.
- Experiment on effect of water regime and fertilizer application was set up at Sadore station in July 2009 in collaboration with a Norwegian research institute. The experimental set up used a complete randomized bloc design Parameters to monitor are growth, seed yield, survival and insect attacks. Data collection is in progress.
- Effect of pruning was tested in Samanko one year after transplanting. The results show positive effect of pruning on seed yield. One year old trees that were pruned produced an average yield of 183 g compared 137 g for non pruned trees.

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.9 Identification of best propagations techniques (various trials on rooting of cuttings)

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES, and CBOs

Progress/Results:
- A trial was set up in August 2008 at Sadore to compare 4 different propagation and transplanting options: direct seeding, transplanting seedlings, transplanting rooted cuttings and transplanting cuttings. Results after one year indicate that survival of seedlings and rooted cuttings are higher (75-95%) than direct sowing and cuttings less than 20%.

- **Effect of propagation method on root development and plant phenology:** Root system of seedlings raised from cuttings and seedlings were assessed to evaluate effect of propagation option their development. Analysis of data shows that number of roots was significantly higher with cuttings than seedlings. Flowering and fruiting occur earlier for plants propagated from cuttings than seed.

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.10 Jatropha oil cake application as manure

Participating Countries:
Mali, Niger

Participating Partners:
IER, Mali, AMEDD/GERES, and CBOs

Progress/Results:
An experiment was set up at Sadore station to evaluate effect Jatropha oil cake application as manure on millet production and soil fertility. The experimental design is a randomised complete bloc design with 6 treatments and four replicates: T_0, T_1 and T_5 were assigned to plots without fertilizer, plots with 100 kg ha^{-1} NPK (15, 15, 15) and plots with 60 kg ha^{-1} NPK (15, 15, 15) applied in micro dose. T_2, T_3 and T_4 are plots amended with 10 t ha^{-1}, 5 t ha^{-1} and 2.5 t ha^{-1} of Jatropha oilcake fertilizer respectively. The results of first year are as follow:
- Amendment of plots with Jatropha oilcake at the rates: 10 t; 5 t and 2.5 t ha^{-1} resulted in an increased number of tillers by 87.98%; 67.35% and 46.97% when compared to the plots without fertilizer and these differences were significant. Plots with 10 t ha^{-1} of Jatropha oilcake fertilizer resulted in 18% increase in number of tillers when compared with plots amended with 100kg NPK (15, 15, 15)/ha.
- The application of Jatropha oilcake resulted in a significant increase of 192.86%, 132.54% and 94.44% of grain yield for T_2, T_3 and T_4 plots compared to the T_0 plots.

Albert Nikiema and Modibo Sidibe

Activity 7.4.1.11 Black rot in *Jatropha curcas* caused by *Botryodiplodia sp*

Participating Countries:
India

Participating Partners:
ICRISAT, WCUSS, READ, CRIDA, IER, Mali

Progress/Results:
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has been exploring the use of *Jatropha* for rehabilitating the marginal lands. We observed large scale mortality of 3-4 years aged *Jatropha* plants in the plantations during June 2009, which we thought initially, might be due to the prolonged drought on the failure of pre monsoon precipitation during March-April 2009. However, when we closely examined the dead plants, we observed the symptoms of shriveling and discoloration of stems the base of plants. Black colored lesions (rotting) under the dark as well as cambium regions of the stem confirming the disease besides the impact of drought were also observed.

The cultures we isolated from the stems of *Jatropha* showing symptoms of rot for identifying the potential pathogens associated with the affected areas. Microscopic examination of the affected plant tissues revealed the presence of scattered globose pycnidia near the margins of black lesions. Conidia were ovulate, hyaline, aseptate, mostly single celled and measured 20-32x12-15 μm and bi-celled brown matured conidia were also observed. The organism was identified as *Botryodiplodia sp* based on the characters of matured bi-celled conidia and on morphological observations through microscopy. Black lesions on affected stems of *Jatropha* were surface disinfected (5% sodium hypochlorite), cultured on Potato Dextrose Agar (PDA) media petri plates through repeated culturing method and incubated at room temperature (25°C). The isolate was identified as *Phoma* sp., an Ana morph of *Botryodiplodia sp* on the basis of colony morphology *in-vitro* on PDA and hyphae characteristics studied under microscopy. Colonies on PDA were gray to black in color with regular margin immersed along with light gray aerial mycelium and the mycelium is hyaline and septate. *Botryodiplodia sp* is a pathogenic fungus causing black rot in many of the plants including tree species.

The pathogenicity test were also confirmed the pathogen *Botridiplodia sp* after culturing the isolates in PDA, from the artificially infected *Jatropha* plants. To our knowledge, this is the first report of pathogen *Botridiplodia sp* causing block rot and resulting in severe damage in *Jatropha* block plantation.

S Marimuthu, SP Wani, Piara Singh and Belum S Reddy

Activity 7.4.1.12 Demonstrating best-management practices for improving sweet sorghum yield

Participating Countries:
India

Participating Partners:
NRCS, IICT, and NGOs

Progress/Results:
The soil analyses of Ibrahimpatnam revealed that there was significant deficiency of sulfur, organic carbon and zinc in these soils. More than 84% of the farmer's fields in Ibrahimbad cluster were found deficient in sulfur, followed by the deficiency of organic carbon in 65% of the fields. Similarly, 50% of the fields were deficient in Zinc; 38% of the fields deficient in boron, whereas 29% of the fields deficient in exchangeable potassium. The soil analysis data revealed that pH of soils ranged from 6.5 to 8.7 falling in neutral to saline category for soil reaction, while electrical conductivity of the soils was in normal range (0.10 to 0.28). The improved management practices evaluated were improved genotype (CSH22SS), sowing with tropicultor and balanced nutrition based on soil testing, includes 90 kg N (in three equal splits), 40 kg P_2O_5, 40 kg K_2O, 30 kg S, 10 kg Zn and 0.5 kg B per ha. The size of the demonstration: one acre. Sweet sorghum was sown on 24th July 2009 and harvested on 30th October 2009. The sampling area for yield was 12 m^2 (3 spots from each demonstration). Observations at harvest were taken on plant height, stem girth at 10 cm, number of internodes at harvest, stalk yield, juice yield and TSS (Table 6). Mean stalk yield, juice yield and total soluble salts (TSS) were 33.6 t ha^{-1}, 11.1 t ha^{-1} and 19.0, respectively.

Table 6. Stalk and juice yield, TSS and other plant characteristics recorded at harvest of sweet sorghum.

Details	Plant height (cm)	Stem girth at 10 cm	No. of internodes	Stalk yield (t ha^{-1})	Juice yield (t ha^{-1})	TSS (%)
Farmer 1	276	6.0	10.7	43.1	16.8	18.4
Farmer 1	262	5.7	10.5	37.9	11.8	18.7
Farmer 1	264	6.5	11.5	27.7	7.9	20.3
Farmer 1	263	5.5	10.8	25.6	7.6	18.7
Mean	266	6.0	10.9	33.6	11.05	19.0

S Marimuthu, SP Wani, Piara Singh and Belum S Reddy

Activity 7.4.1.13 Effect of ethephon (growth hormone) foliar application as ripening on sweet sorghum productivity under rainfed situation

Participating Countries:
India

Participating Partners:
NRCS, IICT, and NGOs

Progress/Results:
Four concentrations of the growth hormone (50, 100, 150 and 200 ppm) were tested on the productivity sweet sorghum (Cultivar: CSH 22SS). The crop was sown in July 2009 and the growth hormone was applied ay milky dough stage. Stalk juice yield slightly improved with increasing concentration of hormone application, where as TSS was not affected (Table 7).

Table 7. Effect of growth hormone on stalk and juice yield and TSS of sweet sorghum.

Treatment details	Stalk yield (t ha^{-1})	Juice yield (t ha^{-1})	TSS (%)
Control	34.6	13.6	19.0
Ethephon @ 50ppm	35.3	14.8	17.7
Ethephon @ 100ppm	35.0	15.7	17.4
Ethephon @ 150ppm	36.9	16.4	17.7
Ethephon @ 200ppm	39.6	17.0	17.7

S Marimuthu, SP Wani, Piara Singh and Belum S Reddy

Activity 7.4.1.14 Sowing date × genotypes on sweet sorghum productivity during rainy season

Participating Countries:
India

Participating Partners:
NRCS, IICT, and NGOs

Progress/Results:
To study the effects of early sowing on the productivity of sweet sorghum, the improved cultivars of sweet sorghum (CSH 22SS, SSV 84 and ICSA5 x SPV 1411) were grown on May 21 and June 10. Early sowing increased both the stalk and juice yield of sweet sorghum. May sowing had a stalk yield of 53.8 t ha^{-1} and juice yield of 21.3 t ha^{-1}; whereas June sowing had a stalk yield of 51.2 t ha^{-1} and juice yield of 18.6 t ha^{-1}. Stalk yield of cultivars ranged from 45.4 to 59.1 t ha^{-1}, CSH22SS being the highest yielder. Whereas, the juice yield was the highest with ICSA 52 x SPV 1411. Total soluble solids concentration in the juice ranged from 12.3% to 15.3% across cultivars and sowing dates (Table 8).

Table 8. Effect of sowing dates and cultivars of sorghum on stalk and juice yield and TSS.

Treatment details	Stalk yield (t ha^{-1})	Juice yield (t ha^{-1})	TSS (%)
Sowing dates			
May 21st sowing	53.8	21.3	12.3
June 10th sowing	51.2	18.6	15.3
Genotypes			
ICSA 52 x SPV1411	53.0	24.4	12.8
CSH 22SS	59.1	19.6	14.8
SSV84	45.4	15.8	14.4

S Marimuthu, SP Wani, Piara Singh and Belum S Reddy

Output target 2012 7.4.1 Potential proof of concept for use of environment- friendly alternative sources of energy using biodiesel as an energy source

Achievement of Output Target:
30%
From 2010 rainy season onwards *Jatropha* seeds from block plantation at Velchal and Kothlapur will be available for use in decentralized oil extraction and energy production in Velchal. During next three years assessment results of this initiative will be available.

 Activity 7.4.1.1 Decentralized energy model based on use of SVO in stationery engines for power generation established (30%)

Participating Countries:
India

Participating Partners:
Government of AP, READ, KoEL, GTZ, India.

Progress/Results:
Through Public Private Partnership with Kirloskar Oil Engines Ltd (KOEL)- Velchal Village Bio-Energy Committee (VVBEC)-ICRISAT and GTZ decentralized energy production using straight vegetable oil to generate electricity in the village has been initiated in 2009. The construction of the shed to host the oil extraction unit and diesel power generation set is completed. VVBEC has been firmed and registered the Memorandum of Understanding for the public-private partnership with the VVBEC has been completed. The training of the operators for operating Jatropha seed oil extraction unit has been completed. The Self-Help Groups who are managing degraded common property resources, Jatropha plantation have been completed for management of plantation through pruning, basin management and nutrient management options for enhancing the productivity of Jatropha.

SP Wani, S Marimuthu and Ch Srinivasa Rao

MTP Project 9: **Poverty alleviation and sustainable management of land, water, livestock and forest resources through sustainable agro-ecological intensification in low-and high-potential environments in the semi-arid tropics of Africa and Asia**

Project Coordinator: Peter Craufurd

Major findings

- Weather-based agro-advisories to enhance the decision making capacity of farmers in selecting crops and management practices through the use of seasonal forecasts have been tested in Kenya and Zimbabwe. These suggest that farmers have some indigenous knowledge of the upcoming season. They also suggest that farmers can use the information provided to alter their crop management - given adequate options to do so.
- A report sensitizing the ASARECA Strategic Plan to climate change was completed and an institute innovation system for managing climate variability and change established in ECA
- A set of tools to assist in assessing climate variability and its impacts on agricultural systems has been identified and a core group of professionals in ESA trained in the use of these tools. These tools should enhance decision making.
- A ex-ante analysis of the impacts of climate change suggests that at present low levels of yield achieved by most small farmers the impact of climate change will be small. More significantly, these analyses suggest that with improved management and adapted cultivars farmers can substantially increase yield and cope with climate change.
- A conceptual biophysical model has been designed for whole-farm to landscape carbon accounting based on in situ measurements at two sites in WCA and current remote sensing capabilities. At present the model is limited by high resolution images at appropriate times during the season, and alternate lower resolution sources are being tested.
- Farmer participatory research in parts of MP and Jharkhand have demonstrated that improved water management practices, such as BBF, and balanced nutrient management strategies can raise water-use efficiency and yield.
- In China, the development of a benchmark watershed at Lucheba has resulted in increases in water productivity, increases in the area planted to fodder and forage crops, and an increase in livestock numbers, i.e. intensification. Furthermore, increased livestock production has increased biogas production such that 70% households now have a biogas plant, substantially reducing expenditure on alternative energy sources and pressure on these resources
- Work in Zimbabwe with goats has shown that there is potential to reduce poverty by addressing major identified bottlenecks of goat production, especially mortality, and goat marketing. The setting up of an innovation platform at one location built around goat sales has shown considerable potential to generate income and is an entry point for further production and health orientated interventions

Output 9.1: New tools and methods for management of multiple use landscapes with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output target 2010

Achievement of Output Target:
60 %
Stratified soil sampling protocol fro covering a micro-watershed is developed and applied successfully. Need to scale-up using GIS interpolation to assess soil nutrient status at district level for groundnut and other crops. Improved environment-friendly watershed management options for Alfisols evaluated

Participating Countries:
India

Participating Partners:
Department of Agriculture, Government of Karnataka, University of Agriculture Sciences, Bangalore, Dharwad, IISS, Bhopal; NRCS, Indore; CRIDA, Hyderabad, India

Special Project Funding:
Government of Karnataka, USAID, USA and Sir Dorabji Tata Trust, Sir Ratan Tata Trust

Output target 2010 9.1.1 Stratification criteria for assessing soil chemical fertility parameters

Progress/Results:
In the 2008 Archival Report, we reported a soil sampling methodology, which can be used at the watershed scale. This soil sampling methodology is based on stratified random sampling of the soil sampling units within a watershed; and the sampling units were chosen considering the soil types in the watershed, the major crops, area covered by crop, and the number of farmers owning the land in the watershed. This methodology has been adopted in our subsequent research.

In this report, we report on the additional criteria to be used for stratification of soil sampling in an attempt to further refine the methodology. Discriminant Analysis (DA) is a classical multivariate analysis technique where by a multivariate data set containing number of variables are separated into a number of pre defined groups using discriminant functions, which is linear combination of the variables. We report variability in soil fertility parameters as influenced by surface geology, toposequence position in the watershed and size of the farm holding in a typical watershed in the SAT region of Karnataka, India.

The site selected stretches across two geographical districts Dharwad in central Karnataka, where soils were developed on the oldest rocks and the main rock types exposed were either of Archaeanage (granites) or archean to proterozoic age (argillite/grewacke) and Haveri that had the genesis from Chitradurga groups of rocks. The first level stratified the soils in the entire region based on their geological make-up. Two micro watersheds were selected for soil sampling in Haveri and one micro watershed in Dharwad District with production system. Each

micro watersheds ranged in geographical size from 500-1000 ha. Within each micro watershed, fields for soil sampling were identified by a stratified random sampling technique described in Sahrawat et al. (2008).

Stratification of the fertility data into subtypes based on the toposequence position, not only enhanced the statistical power of the analysis but also reduced the effect of soil heterogeneity. Discriminant analysis of the data, grouped the variables into two significant functions, the first function explained about 85.9% variations and the second function explained about 14.1% of the total variations. The positive coefficients for the first function were related to the high values of pH and higher concentrations of potassium (K) and Cu in the soil. The first function separated the toposequence position in the watersheds from the mid and toe positions, with the farmers fields on the toposequence position corresponding to the negative coefficient values of total N and Mg. The second function was related to the sodium (Na), which varied across the topography within the watersheds. A positive score of this function (higher Na contents) generally corresponded to the farmers fields in the toe slope or bottom positions of the watershed, indicating high concentrations of Na in most of the fields in the toe slope position. The results suggests that, for a subset of the soil variables evaluated, mainly pH, K, Cu stratification strategy by the toposequence explained up to 86% of the observed differences. In particular, fields in the up slope position were well separated from the mid and toe slope fields, with very little overlap, by the first function in the DA. Higher concentration of Mn, in the upslope position than in the middle or toe slope positions within the watershed suggested the importance of surface geology on the fertility. Parent materials rich in mafic and ultra mafic rocks with high quantities of Mn result in soils rich of Mn.

Categorization based on land size into marginal, small and large farmers within each toposequence position did not vary significantly for the measured variables in the DA. The first function was related to the positive coefficients of pH, EC, Mn, Zn, K, Na and Ca and negative coefficients of Mg, total N, P, Cu and OC. The second function was related to the positive coefficients of Mg, total N, pH, EC, Mn, Zn, Cu and negative coefficients of P, OC, Ca, Na and K. Apart from soil geology, land use and soil management practices had profound influence on the nutrient status and the redistribution of nutrients in the soil profile

The results of our study based on the proposed soil sampling scheme clearly indicated that deficiencies of P, S, Zn and B are responsible for soil nutrient related limitations to the crop productivity in the SAT region of Karnataka. Discriminant analysis performed for the data sets revealed that the stratification scheme or methodology followed was able to capture the soil variability and heterogeneity except for the use of the land holding size. However, such a sampling strategy may be applicable to a region with uniform soil management practices like low nutrient input.

<div align="right">KL Sahrawat, SP Wani, BK Rajashekhar Rao and Ch Srinivasarao</div>

Output target 2010 9.1.2 Analysis of water non-limiting and water limiting yields and yield gaps of groundnut in India using CROPGRO-Peanut Model

Progress/Results:
To assess the scope for enhancing productivity of groundnut (Arachis hypogaea L.) in India, well-calibrated and validated CROPGRO-Peanut model was used to assess potential yields (water non-limiting and water limiting) and yield gaps of groundnut for 18 locations representing major groundnut growing regions of India. The average simulated water non-limiting pod yield of groundnut for the locations was 5440 kg ha^{-1}, whereas the water limiting yield was 2750 kg ha^{-1}, indicating a 49% reduction in yield because of deficit soil moisture conditions. As against this, the actual pod yields of the locations averaged 1020 kg ha^{-1}, which was 4420 and 1730 kg ha^{-1} less than the simulated water non-limiting and water limiting yields, respectively. Across locations, the simulated water non-limiting yields were less variable than water limited and actual yields, and strongly correlated with solar radiation during the crop season (R2 = 0.62, P £ 0.01). Simulated water limiting yield showed a significant positive, but curvilinear relationship (R2 = 0.73, P ≤ 0.01) with mean crop season rainfall across locations. The relationship between actual yield and the mean crop season rainfall across locations was not significant, whereas across seasons for some of the locations, the association was found to be significant. Total yield gap (water non-limiting minus actual yields) ranged from 3100 to 5570 kg ha^{-1}, and remained more or less unaffected by the quantity of rainfall received across locations. The gap between simulated water non-limiting and water limiting yields, which ranged from 710 to 5430 kg ha^{-1}, was large at locations with low crop season rainfall, and narrowed down at locations with increasing quantum of crop season rainfall. On the other hand, the gap between simulated water limiting yield and actual farmers yield ranged from 0 to 3150 kg ha^{-1}. It was narrow at locations with low crop season rainfall and increased considerably at locations with increasing amounts of rainfall indicating that type of interventions to abridge the yield gap will vary with the rainfall regimes. It is suggested that improved agronomic management (such as high yielding cultivars, balance crop nutrition and control of pest and diseases) in high rainfall regimes and rainfall conservation and supplemental irrigations in low rainfall regimes should be the essential components of the improved technologies aimed at abridging the yield gaps of groundnut.

<div align="right">VS Bhatia, P Singh, AVR Kesava Rao, K Srinivas and SP Wani</div>

Output target 2010 9.1.3b Increasing agricultural productivity and sustaining natural resources in SAT Alfisols (RW2 watershed)

Progress/Results:
Sustaining agricultural productivity and conserving natural resources is still a major challenge on SAT Alfisols. Our present knowledge does not provide a clear and tested approach particularly on land- and soil-management techniques that are effective in reducing runoff and erosion, improving structural stability to the soil, improving water-storage characteristics, and reducing sealing and crusting. The on-station Alfisols watershed was initiated in 2002 to answer few of these problems on Alfisols.

During 2008-09, the Alfisol watershed had the following treatments, which included two crops and cropping systems, and two management practices.
1. Crops and cropping system: Sorghum (PVK 801)/pigeonpea (ICPL 87119) intercrop and castor (GCH4) as sole crop
2. Management: Farmers practice includes Flat land treatment and fertilizer of 20 kg N ha^{-1} 20 kg P$_2$O$_5$ ha[-1] in both cropping system (sorghum/pigeonpea intercrop and castor sole crop)
3. Improved practice includes BBF land treatment and fertilizer of 40 kg N ha^{-1} 40 kg P$_2$O$_5$ ha[-1] in both cropping system (sorghum/pigeonpea intercrop and castor sole crop)

During 2008, the seasonal rainfall was 894 (Jun-Oct) and total annual rainfall was 1101 mm (Fig.1) with thirteen runoff events. Both the annual runoff and soil loss in the BBF system were significantly (P ≤ 0.05) lower by 42% compared to flat system (Table 1).

Table 1. Annual rainfall, runoff and soil loss from different treatments at RW2 watersheds, 2008.

Parameters	BBF system	Flat cultivation
Seasonal Rainfall (mm)	1101	1101
Seasonal runoff (mm)	133	189
Peak runoff rate (m³/s/ ha⁻¹)	0.148	0.165
Runoff as % of rainfall	12.1	17.1
Soil loss (t ha⁻¹)	5.19	7.36

The tensiometer data shows that the soil moisture at 67.5 cm and 82.5 cm depth were similar in both management options with good moisture from July through September (Figure 1). Crops were sown on 25 June 2008. and yields of all crops were higher in the BBF system compared to flat system (Table 2). The sorghum grain yield was higher by about 9% and the fodder yield by 6%, pigeonpea grain yield by 16% and dry matter by 9%, while castor grain yield was higher by 28% and dry matter by 16% in BBF system over flat system.

Table 2. Crop yield under two land managements at RW2 watershed, 2008-09.

Treatments		Yield (t ha⁻¹)	
Land form	Crop/cropping system	Grain	Dry matter
BBF system	Castor	2.11	4.99
	Sorghum /	3.65	10.69
	Pigeonpea	1.36	2.63
Flat cultivation	Castor	1.65	4.31
	Sorghum/	3.35	10.05
	Pigeonpea	1.17	2.41
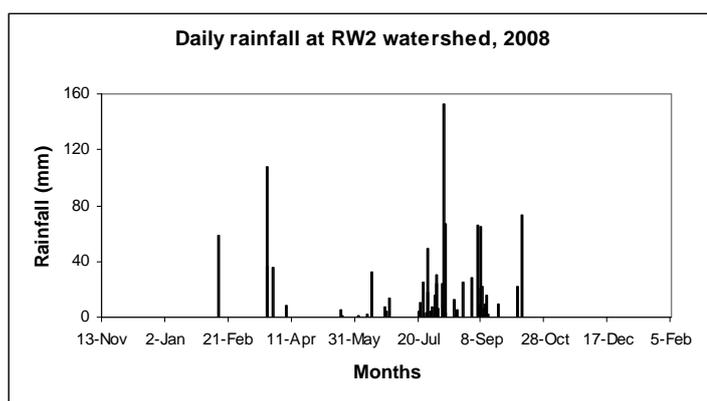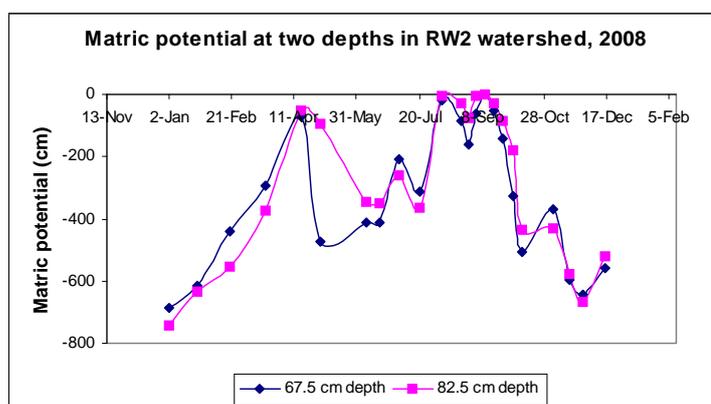
Figure 1. Matric potential and daily rainfall in RW2 watershed, ICRISAT Center 2008

P Pathak, SP Wani and R Sudi

Output target 2009

Achievement of Output Target:
75%
A conceptual biophysical model was designed for whole farm-to-landscape C accounting based on *in-situ* measurements and current remote sensing capabilities. The model was inserted in a FORTRAN based parallel Ensemble Kalman Filter. Various model components were validated individually in two locations in Ghana and Mali. Available very high resolution remote sensing data could not resolve landscape C production by annual crops due to outstanding high uncertainty on acquisition dates relative to peak biomass, delaying full model

assemblage and testing. The proposed accounting system was thereafter modified to use supplementary low spatial resolution, high frequency MODIS imagery for improved annual C production accounting, and data processing is underway to integrate this new data source.

Participating countries:
Burkina Faso, Canada, Ghana, Mali, Niger, USA

Participating partners:
IER (Mali), INERA (Burkina Faso), SARI (Ghana), Univ. Florida (USA), Univ. Sherbrooke (Canada)

Special Project Funding:
SIBWA (BMGF-AgCommons / YCH10), CODEWA (BMZ-CCAAA / YGT20), Aflatoxin Risk Early Warning System (CIDA-CCLF / YCD13)

Output target 2009 9.1.1 Stochastic data assimilation techniques introduced in field-to-landscape research/modeling

Progress/Results:
This output targets the improvement of rural livelihoods in Sudano-Sahelian Africa and the mitigation of greenhouse emissions through Certified Emissions Reductions Credits (CERCs). The general objective is to quantify and reduce C estimation errors and costs and provide recommendations for operational monitoring, reporting and verification (MRV) systems based on remote sensing. Stochastic data assimilation is used to simulate uncertainties alongside expectations. Specific objectives include, for the sites of Sukumba, Mali (dry savanna) and Pisii, Ghana (moist savanna), i/ the development of a simple landscape C model, ii/ model initialization based on satellite and *in-situ* information, iii/ model driving with annual and perennial biomass estimates (from satellite) for 2002-2008 (with associated errors), iv/ development and application of an Ensemble Kalman Filter (EnKF) to simulate C dynamics for 2002-2032.

Research hypotheses are: a two-pool annual model can simulate SOC dynamics (H1); multi-date imagery can estimate field age and, along with catena position, initial SOC (H2); multi-source imagery can estimate annual and perennial biomass production with associated uncertainty (crops and trees: H3); EnKF can reduce error on sequestered C predictions and C accounting costs (H4).

The simple two-pool, annual time step soil organic carbon (SOC) module reported in 2008 was spatially extended from point-scale to cover typical farm scales (in the order of 10 to 1000 ha). An annual plug-in module was developed for tree C dynamics based on a logistic tree growth model for the dominant agro-forestry species in smallholder fields (*Vitellaria paradoxa*). This one-pool module accounts for C accretion in the tree layer inside farmer fields and for C transfers from tree to soil as described in figure 9.1.1.2d1.
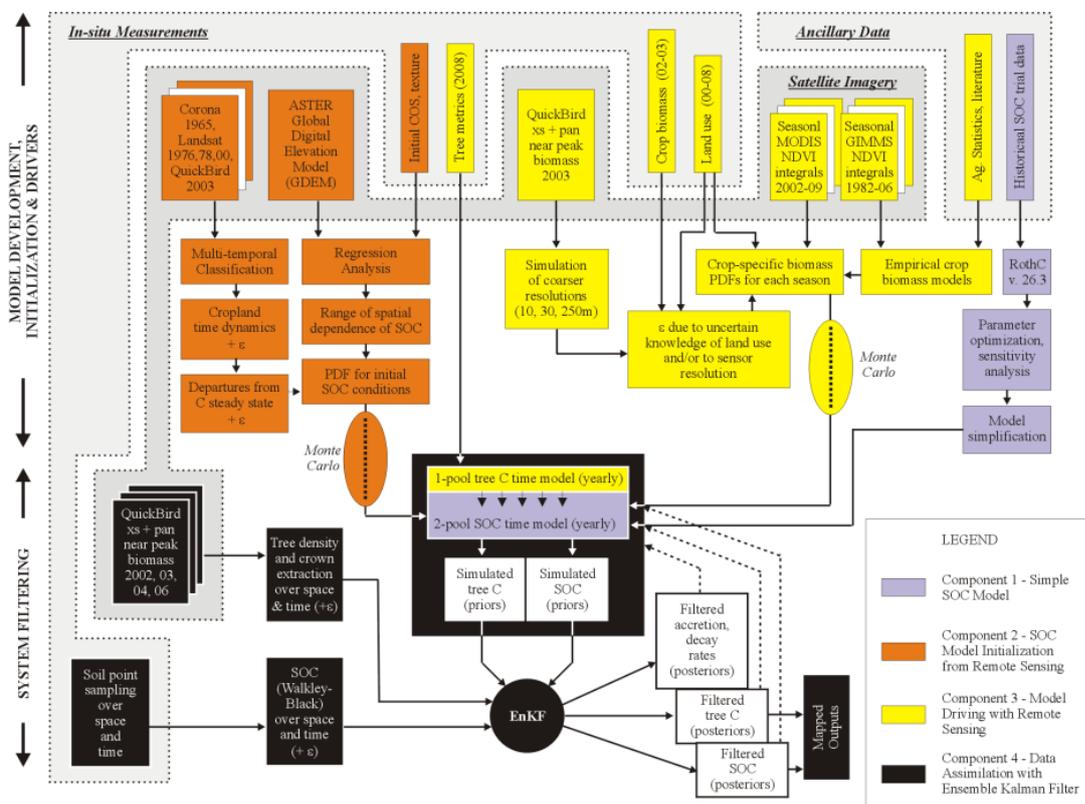
Figure 9.1.1.2d Spatial scheme for simple C accounting system, including SOC
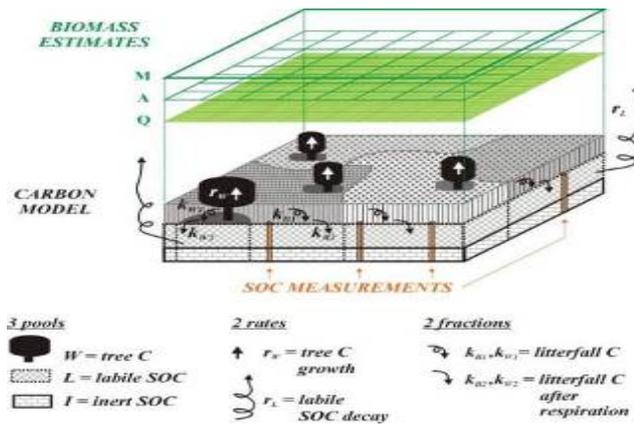
Figure 9.1.1.2d2. articulation of monitoring, reporting and verification (MRV) system components

The flowchart in figure 9.1.1.2d2 shows the articulation of theMRV system components. The upper section of the flowchart details the development of a simple SOC model (grey boxes), its initialization (orange boxes), feeding (yellow boxes) and filtering (black boxes). This representation illustrates different contributions of remote sensing imagery, depending on whether it is assimilated *strictu senso* (in tree C estimation) or only serves as input to the SOC module (tree C shedding, and annual crop residue C estimates). Establishing the reference baseline in C contracts starts with the estimation of initial C (stocks, equilibrium or transient conditions). The characterization of soil properties, cropping systems and land use dynamics often faces a scarcity of historical data. The initial stable SOC fraction (which controls the depletion or sequestration potential) cannot be directly measured. Meanwhile direct total SOC determination is subject to high analytical errors and is spatially discontinuous.

Although initial SOC can be technically treated as a random constant among other EnKF filtered states (and can hence be optimized), its initialization remains key given limited C contract durations (~20 years). % SOC and texture were determined for 400 soil samples collected at the landscape level, pre-season in 2004 (200 samples per site). SOC is correlated with soil texture, itself closely linked to catena position in Sudano-Sahelian agro-ecologies. % organic matter data was thus linearly regressed against % silt+clay and altitude (figure 9.1.1.2d3) with the intent of using the latter as a co-variate for initial SOC extrapolation across the landscape. Likewise, a series of 5 images spanning 40 years served to estimate the age of 1314 georeferenced fields (470 of which were monitored during successive field surveys in 2002, 2003, 2004, 2006). Resulting field ages were then used to classify soil sampling locations (figure 9.1.1.2d4) and corresponding SOC values (figure 9.1.1.2d5).
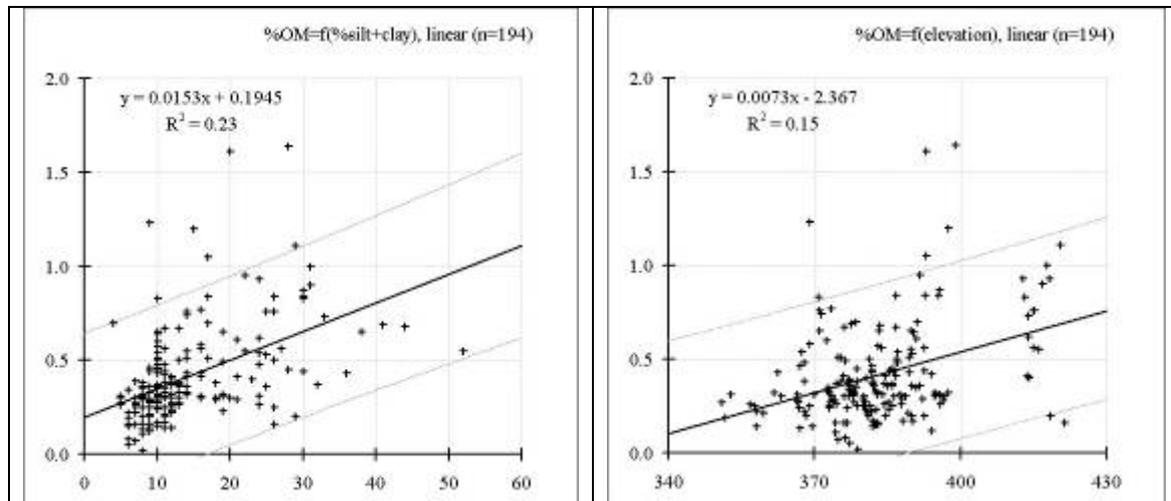
Figure 9.1.1.2d3 Regression of % organic matter (Y-axis) on (a) %silt+clay, (b) altitude (X-axis) for 2004 pre-season samples in Sukumba, Mali. Gray dotted lines are 95% prevision intervals
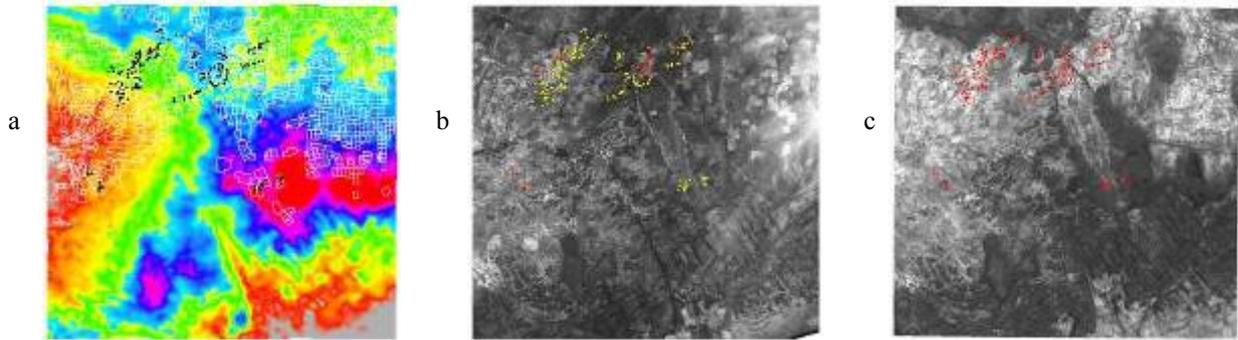
Figure 9.1.1.2d4. Landscape distribution of 2004 pre-season soil samples. A. On top of catena classes; b. Land use at sampling sites in 1965. Cultivated land: red, non-cultivated: yellow (background: Corona image, 10 June 1965); c. as b, but 2004 (background: QuickBird image, 15 June 2004)
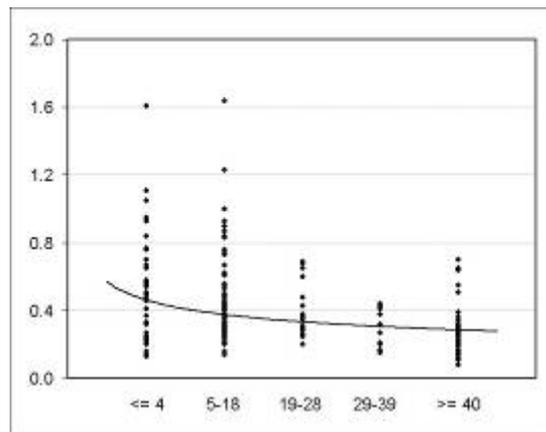
Figure 9.1.1.2d5. Distribution of % SOC (Y-axis) by field age class (years, X-axis). A power trend is fitted to illustrate the analogy with SOC decay over time in fields under cultivation

After the yearly time-step MRV framework is initialized over a set target production system, remote sensing contribution occurs at two levels: driving the simulation of SOC dynamics (through provision of C inputs via yearly pulses of crop residues and tree litter – objective iii) and filtering the simulation of tree C states (objective iv). Remote sensing data assimilation, *strictu senso*, is restricted to the latter only. Theoretically, assimilation of high-frequency (e.g. daily) satellite data may also contribute to improved estimates of annual C production by plants if the MRV system included a plant growth prediction model operating on similar time steps. However, this possibility is practically restricted to very large, homogeneous (e.g. commercial) fields due to the limited spatial resolution of high-frequency imagery. This option is therefore not included here for smallholder conditions.

The approach to assimilation of tree biomass in the MRV framework involved ground collection of tree metrics and estimated age in the Sukumba site, calibration of a simple logistic growth model to *Vitellaria paradoxa* (by far the most dominant species in farmer's fields), and the optimization of a circular Hough transform to automate extraction of tree densities and metrics on a landscape scale. Average (±std. dev.) tree densities (all sp.) per hectare in farmer fields extracted along a positive, monotonic moisture transect of Sahelian-Sudanian-Guinean sites range from 3.4±5.9 (Serkin Hawsa, Niger; n=) to 6.8±7.8 (Tegena, Mali; n=), 8.6±8.4 (Nobere, Burkina Faso; n=), 9.5±7.3 (Sukumba, Mali; n=), 10.8±11.8 (Fansirakoro, Mali; n=), and 13.6±12.3 (Pisii, Ghana; n=), also reflecting changes in rural population densities and space saturation across the sites. Figure 9.1.1.2d6 illustrates the solid performance of automated object detection, here using the circular Hough transform on panchromatic data, for tree centroid extraction (omission error: 11%; commission error: 2%). Work is ongoing to assess remote sensing performance at monitoring changes in tree metrics over time (estimated crown perimeter).

Figure 9.1.1.2d7 provides results of using various in-situ SOC sampling strategies to filter SOC predictions. For 12 experimental fields in the moist savanna site of Pisii, Ghana, the continuous black line shows the mean expected value for an ensemble of SOC propagations (after filtering), and the dashed black line represents the "real value" simulated by the SOC module and used as reference. Grey lines represent ±1s around the ensemble mean. « X » symbols represent aggregate estimates of SOC over space based on field measurements only. If a field is not sampled in a given year, its SOC value is set as the mean value calculated across other fields on that year. EnKF consistently produces estimates that also closer to "real values" than individual measurements. In (a), each of the 12 fields is measured every year. Variance in SOC estimates decreases as new measurements are assimilated over time, but remains higher if only 3 unique fields (out of 12) are sampled every year (b). Variance of the estimates evolves differently in non-sampled fields, compared to sampled fields. Compared to a complete sampling scheme (12 fields per year) SOC is over-estimated when only 3 unique fields are repetitively sampled every year (b vs. c) or when no measurement is available at all (d). However, a 3-field rotative sampling approach suffices to improve the accuracy of estimates (c).
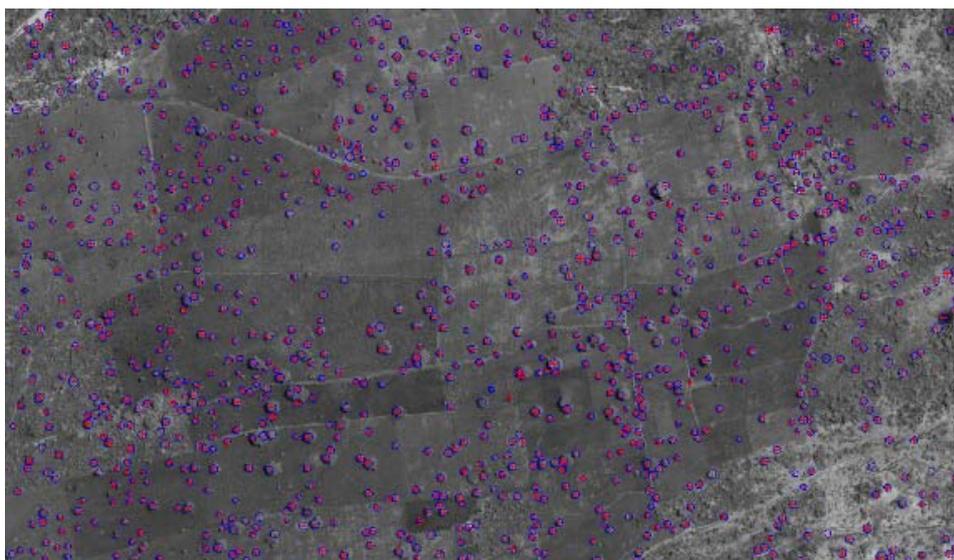
Figure 9.1.1.2d6. Tree centroid detection (red cross) and crown perimeter delineation (blue outline) after optimization of a circular Hough transform (). Farm of Mory Konaté, Sukumba site, Mali
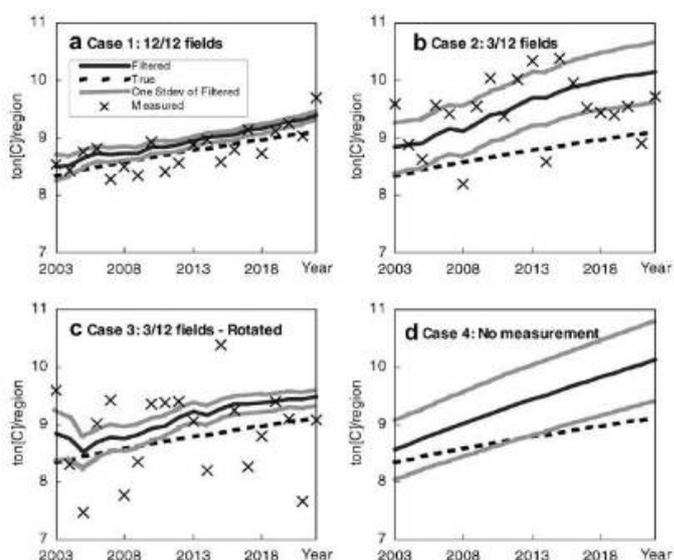
Figure 9.1.1.2d7 (above). Effect of different SOC sampling schemes on SOC level estimates from EnKF over 12 experimental fields in the site of Pisii, Ghana (cumulative area: 0.54 ha)

PCS Traore

Output 9.2: New tools and methods for management of climatic variability, with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output target 2009

Achievement of Output Target:
100 %
Crop-simulation models successfully used to assess impact of climate variation based on early season prediction of rainfall to select suitable cropping systems

Participating Countries:
India

Participating Partners:
ANGRAU, Regional Agricultural Research Station, Nandyal Andhra Pradesh, India

Special Project Funding:

Output target 2008

Output target 2008 9.2.1 Ex-ante analysis of cropping systems options in relation to ENSO phase for Nandyal in Andhra Pradesh, India

Progress/Results:

Collected the past 46 years (1961-2006) of weather data for Nandyal (latitude 15º29" N, longitude 78º29" E), which comprised of daily values of solar radiation, maximum and minimum temperature and rainfall. The site has mean annual rainfall of 800 mm and mean seasonal rainfall (June to September) of 560 mm. Of all the weather years 26% were El-Niño, 28% La-Niña and 46% Neutral years. Mean rainfall for the La-Niña, Neutral and El Niño years is 970 mm, 760 mm and 690 mm, respectively. Mean seasonal rainfall (June- September) for the La-Niña, Neutral and El-Niño years is 710 mm, 520 mm and 480 mm, respectively. The soils at the site are high water holding capacity Vertisols and mixed black soils.

Total rainfall for the period July to October was correlated with both SOI and SST anomalies (Niño 3.4 region) for the period May to October. Correlations of rainfall with SOI were better than those with SST anomaly. Based on this relationship the SOI with SSTA, SOI value of 5.0 corresponded with SSTA value of -0.5, a SSTA threshold value for the La-Niña condition, and the SOI value of -7.0 corresponded with the SSTA value of 0.5, a SSTA threshold value for the El-Niño condition. Thus, if the SOI of a year for the period May to September was above 5.0 it was considered as a La-Niña year and if below -7.0 then it was an El-Niño years. The years between these two SOI values were taken as a Neutral years.

We used crop models available in APSIM software to simulate growth and yield of (three sequential systems and three intercrop systems). The sequential systems were maize-chickpea (MZ-CP), soybean-chickpea (SB-CP) and groundnut-chickpea (GN-CP). The intercrop systems were maize/pigeonpea (MZ/PP), soybean/pigeonpea (SB/PP) and groundnut/ pigeonpea (GN/PP).

Considering recommended agronomic management conditions, the simulation of crop yields was carried out for 46 years using weather data from 1961 to 2006. The outputs of crop yields and net incomes of each year were categorized into three ENSO classes (El-Niño, La-Niña and Neutral phases. A cropping system was ranked high in performance if its net income was high and its CV in net income was low. Among the rainy season crops studied, maize was the most sensitive crop to the phases of ENSO. Mean yields of maize for the El-Niño phase were 76 to 87% of yields obtained for the La-Niña phase in the sequential and intercrop systems (Table 1). In case of soybean and groundnut the changes in yield because of ENSO phases were much less. This is due to the fact that because of sufficient seasonal rainfall and high water holding capacity of the soil at Nandyal, the chances of meeting the water requirements of these two crops are very high. Between the two post-rainy season crops, chickpea was more sensitive to ENSO phases than pigeonpea. Yield reductions of chickpea and pigeonpea from the La-Niña to El-Niño phase were the largest (46 to 62%) in the groundnut-based systems than in the soybean and maize based systems.

The major influence of ENSO phases was on the variability in crop yields, especially for the postrainy season crops. Except for the maize crop, the ENSO phases had a marginal influence on the variability in crop yields of rainy season crops (Table 1). However, for the postrainy season crops of chickpea and pigeonpea, the CV in yields was the lowest for the La Niña phase and significantly increased for the Neutral and El Niño phases of ENSO. The CV in yield of the post-rainy season crops was the highest for the Neutral phase.

Table 1. Economic yields of component crops and total productivity of the cropping systems during ENSO phases.

Cropping systems	Rainy season crop		Postrainy Crop		Total	
	Yield	CV(%)	Yield	CV(%)	Yield	CV(%)
	La Niña phase					
MZ-CP	3480	52	1480	7	4970	37
MZ/PP	3260	16	820	34	4080	11
SB-CP	1730	37	1400	9	3130	21
SB/PP	1140	36	1550	15	2690	21
GN-CP	1850	14	1290	27	3130	15
GN/PP	1090	16	1510	19	2600	14
	Neutral phase					
MZ-CP	3270	54	1030	46	4300	44
MZ/PP	2850	37	740	37	3590	28
SB-CP	1600	30	850	58	2440	33
SB/PP	1080	29	1090	34	2170	26
GN-CP	1860	14	630	81	2480	20
GN/PP	1250	15	940	42	2200	14
	El Niño phase					
MZ-CP	2660	60	1150	32	3810	46
MZ/PP	2820	28	860	34	3680	19
SB-CP	1550	33	760	56	2300	29
SB/PP	1060	28	960	25	2020	23
GN-CP	1860	13	490	85	2350	20
GN/PP	1310	25	810	35	2120	15

Total productivity of cropping systems was the highest during the La-Niña phase of ENSO with the lowest CV in yields as compared to the other phases. The maize-based cropping systems (MZ-CP and MZ/PP) were the most productive systems during all the phases of ENSO. This was followed by the soybean-based and groundnut-based systems. In maize-based systems, total productivity ranged from 4000 to 5000 kg ha^{-1} for the La Niña phase, whereas in other phases it ranged from 3600 to 4300 kg ha^{-1} (Table 2). The relative performance of cropping systems in terms of productivity followed the same trend across different phases of ENSO. Except for the groundnut-based systems, the CV in total productivity for the maize- and soybean-based systems was the highest for the Neutral phase. Among the cropping systems, the CV in yields was less in the intercropping systems as compared to sequential systems, indicating the stability in yields albeit at lower levels of productivity.

A cropping system was considered to be most promising if its net income was high and CV in net income was low. Comparison of the performance of cropping systems in the La Niña rainfall years with the high rainfall years showed that in both the cases three copping

systems, namely GN-CP, GN/PP and SB/PP had both higher net income and the lower CV as compared to the other cropping systems (Table 2). In case of Neutral years the most promising cropping system was GN/PP. Similar results were obtained of cropping systems in the El-Niño years. The promising systems were MZ/PP and GN/PP intercrop systems and the worst were the SB-CP and MZ-CP in terms of economic gain and risks to net income. These results on the performance of cropping systems indicate that if we are able to predict the phases of the ENSO prior to the onset of the rainy season, then we can provide more suitable cropping systems options to the farmers to reduce climatic risks.

Table 2. Net income (rupees) from four cropping systems at Nandyal, Andhra Pradesh as influenced by SST anomaly.

SST anomaly	Net income (Rs.)	CV (%)	Net income (Rs.)	CV (%)
	Maize/Pigeonpea		*Maize-Chickpea*	
El-nino	12000	61	11730	92
Neutral	13440	72	11630	90
La-nina	16720	41	16960	47
All years	14050	56	13550	70
	Soybean/Pigeonpea		*Soybean-Chickpea*	
El-nino	11290	22	13210	49
Neutral	13400	61	10730	76
La-nina	17520	33	18270	47
All years	14070	44	14270	56

Piara Singh, K Srinivas, V Nageswara Rao and T Giridhara Krishna

Output target 2008 9.2.1 Greater application of climate predictions and cropping practices by NARS, extension agencies and farmers to manage climate risks in Africa and Asia

Achievement of Output Target:
100%

Participating Countries:
Kenya

Participating Partners:
Kenya Meteorological Department, University of Nairobi, Kenya Agricultural Research Institute and Ministry of Agriculture

Progress/Results.
One of the applications developed is aimed at enhancing the decision making capacity of the farmers in selecting crops, varieties and management practices through the use of seasonal climate forecasts issued by various organizations. The application focused on developing "Weather based agro-advisories" in which probabilistic forecasts are interpreted and presented in a way that can easily be understood by the end users. The advisory provides information on various management options that are suited to the predicted season and enables farmers to make tactical decisions while selecting crops, varieties, area to be cultivated, allocating land for various crops, and other investment decisions. In the past advisories were developed based on the forecast issued by KMD. However, forecasts are also available from advanced institutions like IRI and ECMWF which are produced using the latest developments in forecasting technology. Now the advisories are developed taking into consideration forecasts from all these institutions. This improved significantly the reliability of the information provided. The usefulness of the information presented through advisories was evaluated during the stake holder meetings held at Kitui, Mwingi and Mutomo. In general, farmers found the information very useful and have shown keen interest in receiving the advisory. However, it is unclear how farmers are using this information, what decisions they have taken based on the information provided through advisories, and the value of those decisions in improving productivity or minimizing losses. A survey to assess the impacts of the advisories in reducing risk and improving farm productivity is planned for July/August 2010. The final component of this activity is to work towards institutionalization of this approach by creating awareness about the potential benefits. The progress achieved to date was presented to the director and other staff of KMD and similar presentation will be made to managers from KARI. A formal meeting with the senior level managers from KARI, KMD and Ministry of Agriculture to discuss and chalk out a way forward is scheduled for September 2010.

Special Project Funding:
The project "Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate" supported by IDRC/DFID-CCAA program.

Peter Cooper, KPC Rao and John Dimes

Output target 2008 9.2.1 Greater application of climate predictions and cropping practices by NARS, extension agencies and farmers to manage climatic risks in Africa and Asia

Achievement of output target:
>85%. Project ends in June 2010

Dialogue with farmers, on-farm trials and simulations of yields for two seasons have been successfully completed to test whether seasonal climate forecasts could be successfully used by farmers.
Participating countries:
Zimbabwe and Zambia

Participating partners:
MSU, ZU, UFS, ZARI, Agritex, ZMDS, ZMS, CIAT, CSIRO, smallholder farmers

Progress/Results:
For 2008/09 and 2009/10 cropping seasons, discussion sessions were conducted with smallholder farmers about seasonal climate forecasts (SCF) given out by the national metrological departments of Zimbabwe and Zambia. The workshops were hosted in Sept/Oct each year, prior to the start of the rains. Meetings covered 2 districts in each country (Monze and Sinazongwe in Zambia, Gweru and Lupane in

Zimbabwe). Farmers were also given opportunity to give their own predictions of the forthcoming season based on indigenous knowledge. Simulated yield data using climate of the previous 10 years at each site were also shared with farmers. With the SCF on hand, farmer groups representing participating villages were asked to formulate crop management options for the coming season. Based on farmer inputs, on-farm experimentation was designed to test management responses to the SCF. The on-farm trials formed the basis of Master's and PhD degree studies and were also used to host farmer field days to review the outcome of the SCF and crop responses to the management options tested. Each year, farmer predictions of the seasonal rains closely agreed with the Met Bureau's forecasts - favorable rainfall forecast for the 2008/09 season and un-favorable for 2009/10. In each season the main factors of interest to the farmers were tillage options, variety options and fertility options. A water management option (ridging) was included in 2008/09, largely because of severe waterlogging that was experienced in the 2008 crop. Higher rates of N and longer duration varieties were of interest to farmers in the 2008/09 season, whereas small doses of fertilizer and extra weeding were on interest in the 2009/10 season. Results of the on-farm experimentation conducted in the 2008/09 season across 6 sites showed no response to tillage or variety treatments (unfortunately 2 quite similar maturity types were included by researchers across expts.) but a strong response to fertility inputs. Simulation of trial results in Zambia revealed that sub-optimal plant populations and weed competition were important factors in the final yield outcomes. The conservative nature of the researcher's variety selections was highlighted by a farmer testimonial at a field day in Zambia – he responded to the 2008/09 forecast by growing the longest duration maize variety and fertilizing it well. "I am truly food secure now" was his summation.

Special Project Funding:
IDRC-CCAA

<div align="right">Peter Cooper, KPC Rao and John Dimes</div>

Output target 2009 9.2.2 A report on opportunities for adapting agriculture to climate variability and change in ECA published

Achievement of Output Target:
100%

Participating Countries:
All ten countries in the Eastern and Central African region.

Participating Partners:
ILRI, ICRISAT and Reading University, UK.

Progress/Results:
As part of the ASARECA supported project (*Managing uncertainty: Innovation systems for coping with climate variability and change*) , a multi-authored Research Report was finalized and was released at the second project review meeting in November 2009 with a citation of "Van de Steeg J, Hererro M, Kinyagi J, Thornton PK, Rao KPC, Stern R, Cooper*, P* 2009. *The influence of climate variability and climate change on the agricultural sector in East and central Africa – Sensitizing the ASARECA strategic plan to climate change*. Research Report 22, ILRI. pp 85. ISBN 92-9146-238-1."

The report will be made available to ASARECA in both hard and soft copy for their distribution to key stakeholders with the ECA region.

Special Project Funding:
The project *Managing uncertainty: Innovation systems for coping with climate variability and change* is supported by funds from the African Development Bank.

<div align="right">Peter Cooper, KPC Rao and John Dimes</div>

Output target 2010 9.2.2 Impacts of global climate change projections on SAT agriculture evaluated in at least two countries in ECA.

Achievement of Output Target:
75%
Climate change predictions for Southern Africa have been downscaled and analysed. Modelling impacts using these data is in progress.

Participating Countries:
Kenya, Tanzania, Ethiopia, Sudan

Participating Partners:
Kenya Meteorological Department, Kenya Agricultural Research Institute, Ministry of Agriculture Kenya, Ethiopian Institute of Agricultural Research, National Meteorological Agency, Sudan Meteorological Agency-Sudan, Agricultural Research Corporation-Sudan, Sokoine University of Agriculture-Tanzania, and Tanzania Meteorology Agency

Progress/Results:
In collaboration with the University of Cape Town, South Africa, downscaled climate change projections for two time periods, mid century (2046-2065) and end of the century (2081-2100) were developed for four locations in Kenya using the statistical dowscaling model SDSM. The downscaled projections consisted of climate extension of eleven Global Coupled Models, Canadian Center for Climate Modeling and Analysis CCCMA_CGCM3-1, Centre National de Recherches Météorologiques CNRM-CM3, Geophysical Fluid Dynamics Laboratory GFDL_CM2-0, Commonwealth Scientific and Industrial Research Organization CSIRO-MK3, & CSIRO-MK3-5, Max-Planck-Institute for Meteorology in Hamburg Fifth generation of the atmospheric GCM MPI-ECHAM-5, Meteorological Research Institute, Japan MRI-CGCM2 3.2 and the Goddard Institute for space Studies GISS-model-e-r Meteorological Institute of the University of Bonn, Germany MIUB-ECHO-G and the Institute Pierre Simon Laplace IPSL-CM4.

Analysis of the downscaled projections is completed. The temperature projections are consistent with the observed and projected increases in the fourth IPCC report for East Africa region. The rainfall projections, especially for Katumani, showed a significant increase over the current levels (Table).

Prediction	Expected change in rainfall (%)							
	2046-2065				2081-2100			
	Katumani	Kitui	Mwingi	Mutomo	Katumani	Kitui	Mwingi	Mutomo
Min	23.9	-10.7	-4.4	-4.5	30.9	-11.5	-4.8	9.3
Med	41.0	17.0	-0.1	9.1	70.9	24.2	15.5	13.6
Max	57.6	58.2	22.8	58.2	96.9	58.8	33.9	58.1

The data is currently formatted for use with crop simulation model APSIM to assess the impact of projected changes on the performance of crops and cropping systems relevant to the region.

KPC Rao, Peter Cooper and John Dimes

Output target 2010 9.2.3 A synthesis report on "Tools and methodologies to assess climate vulnerabilities and support informed decision making for improved management of agricultural systems in ECA" published

Achievement of Output Target:
90%
A set of PC-based tools for the analysis of climate variability and its impacts has been developed, and documentation is under preparation.

Participating Countries:
Kenya, Tanzania, Ethiopia, Sudan

Participating Partners:
Kenya Meteorological Department, Kenya Agricultural Research Institute, Ministry of Agriculture Kenya, Ethiopian Institute of Agricultural Research, National Meteorological Agency, Sudan Meteorological Agency-Sudan, Agricultural Research Corporation-Sudan, Sokoine University of Agriculture-Tanzania, and Tanzania Meteorology Agency

Progress/Results:
The overall aim of this activity is to identify a set of tools that assist in assessing climate variability and its impacts on agricultural systems and train a core group of professionals from each of the four participating countries, Kenya, Ethiopia, Tanzania and Sudan, in using these tools. Initially, an assessment of the data analysis needs and available tools to conduct the required analysis was carried out. The assessment has identified the following areas where new tools and approaches would be of great value in understanding the dynamic nature of climate and how it affects agricultural systems.
1. Data analysis: Tools to analyze the trends in long term climate data
2. System simulation tools: Crop models and other tools that help understand the interactions and inter relationships between climate and agricultural systems
3. Risk and benefits assessment: Tools to evaluate the benefits and risks associated with various agricultural investments

After a careful consideration of the data requirements, and skills requirements, the following tools were identified as the most appropriate for studies related to climate variability and change.
1. INSTAT: A statistical package to analyze the long-term climate data
2. MARKSIM: a stochastic weather generator to generate synthetic data for locations with no observed data and for variables like solar radiation which are required by crop models but availability of observed data is a problem
3. APSIM: a soil-crop-management systems simulation platform to simulate crop growth and yield as a function of climate and management
4. Simple spreadsheet based tools to assess the risks and benefits

Efforts were also made to develop a number of simple spreadsheet based tools to analyse the rainfall and temperature data and to assess the profitability and risks associated with various management options. A document with example applications is under preparation.

KPC Rao, Peter Cooper, John Dimes and Roger Stern

Output target 2010 9.2.3 An institutional innovation system for managing climate variability and change will be established in ECA which will greatly enhance the awareness, competency and collaborative ability of key institutions including NARS, NMS, ASARECA Programs and other key change agents to jointly address climate risk concerns

Achievement of Output Target:
75%
The innovation system comprises results from several climate variability projects with ASARECA, some of which have been completed and are reported above. Proof of concept projects will be reported in 2010.

Participating Countries:
Kenya, Uganda, Rwanda, Sudan and the United Kingdom of Great Britain

Participating Partners:
ICRISAT, ILRI, CIAT, ICRAF, Reading University, UK, Rwanda Met. Services, Kenya Met. Department, Sudan Met. Authority, NARO (Uganda), Jomo Kenyatta University of Agriculture and Technology, ARC (Sudan)

Progress/Results:
The 'innovation system' is comprised of 3 Results from the ASARECA project identified in 2009 Output Target 9.2.2 above. Result 1 is the Research report described above. Result 2 is building the capacity of both NARS and NMS in climate risk analyses which has also been completed during 2009. Result 3 is comprised of 7 "Proof of Concept Projects" being undertaken in Uganda, Rwanda, Kenya and Sudan. These PoC's are designed to illustrate the added value that climate risk analyses (using a range of proven tools) can bring to agricultural research and development.. These PoC's will be completed and reported in 2010.

Special Project Funding:
The project *Managing uncertainty: Innovation systems for coping with climate variability and change* is supported by funds from the African Development Bank.

<div align="right">Peter Cooper, KPC Rao, John Dimes and Roger Stern</div>

Output target 2009 9.2.4 *Ex ante* assessment of climate change on SAT agriculture published.

Achievement of Output Target:
100%

Participating Countries:
Long-term daily climate data from India, Kenya, Malawi, Zimbabwe, Mali and Niger were used for this analysis.

Participating Partners:
ICRISAT staff based in India, Kenya, Zimbabwe and Malawi

Progress/Results:
An article describing the outputs of these analyses was published in December 2009 with the citation of Cooper, P., Rao, K.P.C., Singh, P., Dimes, J., Traore P.S., Rao. K. Dixit, P. and Twomlow, S. (2009) *Farming with current and future climate risk: Advancing a 'Hypothesis of Hope' for rain-fed agriculture in the Semi-Arid Tropics*. Journal of SAT Agricultural Research 7, pp 1-19. The article highlighted the following:-

The analysis was undertaken to test the hypothesis that *"in the medium term (2010-2050), ICRISAT is well placed to help farmers mitigate the challenges and exploit the opportunities that are posed by climate change through: (i) the application of existing knowledge on crop, soil and water management innovations, and (ii) the re-deployment and re-targeting of the existing germplasm of its mandate crops.* Rather than selecting specific climate change scenarios, we chose to undertake a 'sensitivity-based' analysis in which we looked at the impact of a factorial combination of climate change of 5 different temperature increases (1, 2, 3, 4 and 5°C) and 3 different percentage changes in seasonal rainfall. (0%, +10%, and -10%) and compared the outputs with a 'control' of the current climate at each location for which the analyses was undertaken. We undertook three types of analyses.

Firstly we looked at the implication of these climate change combinations for changes in the Length of Growing Period (LGP) and how they might affect the global distribution and extent of the Semi-arid Tropics (SAT).

Secondly, we examined in some detail how these scenarios would impact on crop production (millet, sorghum, groundnuts and pigeonpea) in Eastern, Southern and Western Africa and in India. We also looked, albeit to a lesser extent, at the potential 'fertilizer effect' of enhanced CO_2 levels on crop production.

Finally we examined the potential of improved production practices and better adapted germplasm to mitigate the impact of climate change. Key points emerged from this *ex ante* analyses, namely:
- Climate change will reduce the length of the growing period across the SAT and their geographical distribution, but that this could in large part be mitigated by improved water management innovations and the re-targeting and re-deployment of existing germplasm.
- Predicted temperature increases, through their effect of increasing the rate of crop development, have greater negative impacts on crop production than relatively small (+/- 10%) changes in rainfall.
- The impact of temperature increases alone on the yields under current low input agricultural practice is likely to be relatively small as other factors will continue to provide the overriding constraints to crop growth and yield. Significant reductions in rainfall amounts however would modify this conclusion.
- The adoption of existing recommendations for improved crop, soil and water management practices, *even under climate change*, will result in substantially higher yields than farmers are currently obtaining in their low input systems.
- The development and adoption of better 'temperature-adapted' varieties, together with improved management practices, could result in the almost complete mitigation of the negative impact of temperature increases.

Based on these key outputs, a schematic framework was developed within which ICRISAT will undertake further research to refine and further test this hypothesis. (Figure 1)

Figure 1. 'Hypothesis of Hope' Schematic Framework.
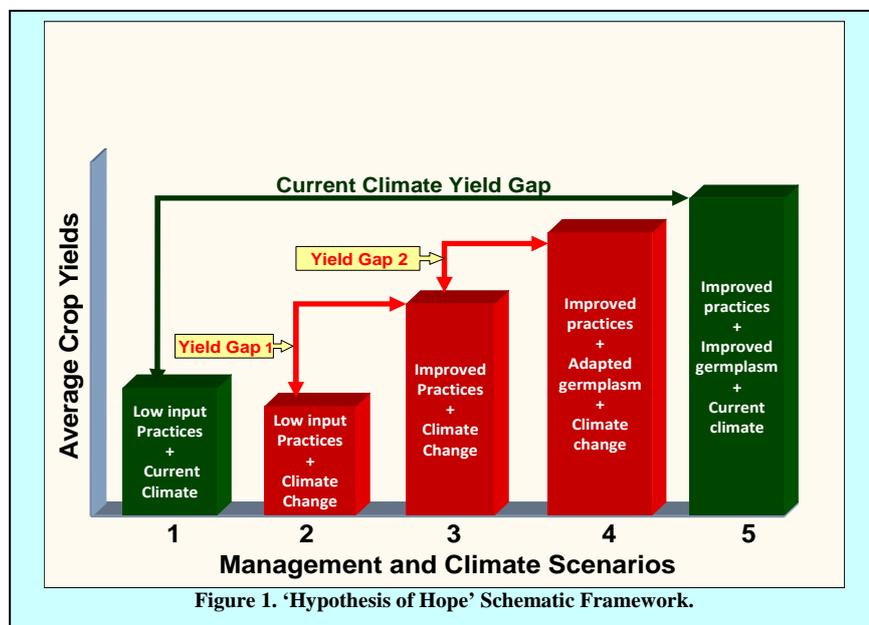
Special Project Funding:
None

Peter Cooper, KPC Rao, Piara Singh, John Dimes,
PCS Traore, K Rao, Prakesh Dixit and Steve Twomlow

Output target 2010 9.2.4 Regional capacities in linking simulation models, participatory on-farm research and climatic forecasting to increase the competencies of smallholder farmers in coping with current climatic variability and adapting to potential climatic change strengthened in East and Southern Africa

Achievement of Output Target:
75%
Training modules and tools have been developed and training courses held. Further courses will be held in 2010.
Participating Countries:
Kenya, Tanzania, Ethiopia, Sudan

Participating Partners:
Kenya Meteorological Department, Kenya Agricultural Research Institute, Ministry of Agriculture Kenya, Ethiopian Institute of Agricultural Research, National Meteorological Agency, Sudan Meteorological Agency-Sudan, Agricultural Research Corporation-Sudan, Sokoine University of Agriculture-Tanzania, and Tanzania Meteorology Agency

Progress/Results:
A training module covering the tools identified under 9.2.3 was developed and a training program involving researchers from Kenya, Tanzania, Ethiopia and Sudan was conducted. A refresher course to brush up and enhance their skills in the use of these tools will be held in 2010. Some aspects of the training module are now used by Institute for Meteorological Training and Research (IMTR), a training affiliate KMD, in their training programs. The Excel based tools are used by all the project partners.

Special Project Funding:
The project "Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate" supported by IDRC/DFID-CCAA program.

KPC Rao, Peter Cooper and John Dimes.

Output 9.3: Affordable and sustainable integrated crop management options developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output target 2011

Achievement of Output Target:
50 %
Integrated crop management options to enhance water nutrient use efficiencies developed and tested in different locations, scaling-up approach need to be assessed in selected areas

Participating Countries:
India and China

Participating Partners:
BAIF, Bhopal; BYPASS, Madhya Pradesh; IISS, Bhopal; JNKVV, Indore*;* BAIF, Rajasthan; CARDS, Madhya Pradesh; JVT, Madhya Pradesh; DEEP, Rajasthan; TSRDS, Jharkand; PRADAN, Jharkand; FES, Rajasthan; CRIDA, MARI, Warangal ; GAAS, Guizhou; YAAS, Yunnan province, CAAS

Special Project Funding:
Ministry of Water Resources, Government of India; Sir Dorabji Tata Trust (SDTT), Sir Ratan Tata Trust (SRTT), Mumbai, India, Ministry of Water Resources, Government of India; WWF; Asian Development Bank (ADB), Manila, Philippines, CA of Rainfed Agriculture

Output target 2011 9.3.1a   Enhancing water use efficiency through farmer participatory action research-cum-demonstration trials in Madhya Pradesh

Progress/Results:

Large areas of deep black soils (Vertisols) in Madhya Pradesh are kept fallow during the rainy season and the crops are sown during the post-rainy season. The rainy season fallow area covers about 1.83 million ha out of 13.2 million ha total cropland in Madhya Pradesh. Four districts of Madhya Pradesh viz. Vidisha, Sagar, Guna and Raisen have large per cent of area under rainy season fallow. A Farmer participatory action research was taken up to enhance the water use efficiency in these four districts of Madhya Pradesh through rainy season fallow management options through improved land and water management systems viz. broadbed and furrow (BBF), improved varieties of soybean (JS 9305), and application of micro and secondary nutrients (50 kg ha^{-1} zinc sulphate for zinc and 2.5 kg ha^{-1} (agribore 20%) for boron).

Significantly higher crop yields and water use efficiency were recorded in the improved management system compared to farmers practice (Table 1). The average soybean productivity increased by 33% due to improved technology (1.59 t ha^{-1} vs 1.20 t ha^{-1}). Highest increase was recorded in Raisen district (65% increase in WUE) and lowest increase was recorded in Guna district (9% increase in WUE).

Table 1. Soybean grain yield in improved system* and farmers practice in water use efficiency trials, Madhya Pradesh, during rainy season, 2008-09.

District	No. of Farmers	No. of Villages	Area (ha)	Grain yield (t ha^{-1})		% Increase in WUE
				Improved system	Farmers practice	
Vidisha	20	4	44.5	1.46	1.26	16
Raisen	14	4	23.6	1.97	1.19	65
Guna	19	2	27.3	1.31	1.20	9
Sagar	9	1	12.0	1.61	1.13	43
Mean	62[#]	11[#]	107.4	1.59	1.20	33

* Improved system include: improved cultivar, BBF, and integrated nutrient management;   [#]Total

The additional monitory benefit with the improved technology was about 27% (Rs. 5000 per ha) compared to the farmers practice over and above the land was used to grow two crops instead of one as normal farmers' practice is prevalent. The water use efficiency (WUE) of soybean production was 4.5 kg mm^{-1} ha^{-1} in improved technology compared with 3.6 kg mm^{-1} ha^{-1} in conventional farmers practice that is 25% increase in the WUE. The cost benefit ratio with improved system was 2.18, while it was 1.67 in farmers practice (about 31% increase in B:C ratio due to improved system).

During postrainy season, The average chickpea productivity increased by 28% due to improved technology (1.62 t ha^{-1} vs 1.27 t ha^{-1}) (Table 2). The water use efficiency (WUE) of chickpea production was 8 kg mm^{-1} ha^{-1} in improved technology compared with 6 kg mm^{-1} ha^{-1} in conventional farmers practice that is 33% increase in the WUE. In the BBF system there was about 30% saving in the irrigation water.

Table 2. Chickpea grain yield in improved system* and farmers practice in water use efficiency trials, Madhya Pradesh, during 2008-09.

District	No. of Farmers	No. of Villages	Area (ha)	Grain yield (t ha^{-1})		% Increase In yield
				Improved system	Farmers practice	
Vidisha	34	4	41	1.77	1.47	20
Raisen	1	1	1	1.45	1.08	34
Guna	12	2	12	1.77	1.39	27
Sagar	21	1	41	1.38	1.19	16
Mean	68[#]	8[#]	95[#]	1.62	1.27	28

* Improve system include: improved cultivar, BBF, and integrated nutrient management;   [#]Total

P Pathak, SP Wani and R Sudi

Output target 2011 9.3.2   Improving agricultural productivity and minimizing land degradation through improved technologies of dryland areas in Madhya Pradesh and Rajasthan

Progress/Results:

To increase agricultural productivity and enhance water use efficiency in Madhya Pradesh through rainy season fallow management options, farmer participatory trials were conducted in 65 villages in 10 target districts of Madhya Pradesh in partnership with our consortium partners. Farmers evaluated broad-bed and furrow (BBF) system by introducing a new, simple implement for making BBF system. As a result of this, the total area under BBF system increased four to five folds compared to the area in the previous years. New BBF maker cum seed drill implement was designed, tested and introduced at several villages in the target districts. The use of the implement results in considerable cost saving as well time for making and planting on BBF system and increased trial area by five folds over 2008 area.

In Rajasthan, on-farm trials with balanced plant nutrient management and/or improved crop varieties for enhancing crop yields and water use efficiency were conducted in the eight target districts of Rajasthan..

The 2009 rainy season crops have been harvested and the recording yield are in process. Observation during the rainy season indicated a better performance by the crops under balanced nutrient management treatment as compared to the farmer's input treatment despite the sub-optimal rains especially during the establishment phase.

SP Wani, P Pathak, KL Sahrawat, G Pardhasaradhi ,
R Sudi, DP Singh and A Subba Rao

Output target 2011 9.3.2   Integrated water and resource management for improved productivity of farming systems through participatory research cum demonstration in Madhya Pradesh and Jharkhand States of India

Progress/Results:

As a part of the activities undertaken during the season to enhance crop productivity through balanced nutrient management strategy, 78 soil samples collected from farmers' fields the Mandla district and were analyzed for pH, electrical conductivity (EC), organic carbon and available plant nutrients (Table 1).

Table 1. Analysis of soil samples from the Mandla District, Madhya Pradesh, 2009.

	pH	EC (dS/m)	Org-C %	Ols-P	Exch-	Avail-S (mg kg^{-1})	Avail-B	Avail-Zn
Range	5.6-- 7.4	0.07---1.6	0.73---2.6	1.1--- 148	113--- 1838	2---79	0.2---1.1	0.2--- 5.7
Mean	6.7	0.37	1.59	39	626	15	0.5	2.4
% deficient			0	17	0	31	45	9

The results showed that the soil samples have salt problem as indicated by the EC results. The soils are moderate to high in organic carbon. All the soil samples were high in exchangeable K. Available P was deficient in 17% of the farmers' fields, available S was deficient in 31% of farmers' fields, boron was deficient in 45% of the samples collected and available zinc was deficient in (11% of the farmers' fields (Table 1).

In Madhya Pradesh a number of trials in 10 villages (two target districts viz. Jhabua and Mandla) with improved agricultural technologies were conducted in farmers fields during 2009 rainy season. These trials were conducted on a total 28 farmers fields. Balanced nutrient application increased crop yields in Madhya Pradesh by 16.5 per cent in case of blackgram 15.5 per cent in groundnut, 22 per cent in soybean and 26 per cent in maize over the farmers' management.

In Jharkhand our work on rice-fallow after harvesting rice showed that with seed priming and balanced nutrient management farmers harvested 900 kg ha^{-1} chickpea (cv.ICCV 10) and 1600 kg ha^{-1} from KaK 2 cultivar. Farmers in Jharkhand preferred kabuli varieties as against the desitrypes preferred by the farmers in Madhya Pradesh. The district choice for kabuli types chickpea in Jharkhand is due to its use as vegetable rather than as grains in Madhya Pradesh.

SP Wani, KL Sahrawat, LS Jangawad, P Pathak and Piara Singh

Output target 2011 9.3.2 Impacts of various watershed interventions on water productivity in China

Progress/Results:
Rainwater use efficiency of some of the major crops rice, maize, groundnut, watermelon and sweet potato during pre- project are 9.5,7.0,2.2,16.4 and 30.4 kg mm^{-1} while post-project are 11.2, 8.1, 2.8, 19.5 and 35.5 kg mm^{-1} respectively. The RWUE increased in the range of 15 – 29 %. Sweet potato had the highest RWUE both during pre- and post project periods compared to other crops and followed by rice, maize and groundnut. While the highest percent increase of RWUE during pre- and post project was recorded in groundnut (29%), followed by watermelon (19%), rice (18%), maize (16%) and sweet potato (15%)

The net storage capacity of five WHS is 37626 m^3, which contributed as effective water conservation. The WHS have played a crucial role in increasing and stabilizing agricultural productivity by increasing substantially RWUE and livelihoods of farmers in the watershed.

The net yield advantage and net monetary benefit per unit of water conserved for crops viz. rice, maize, groundnut, watermelon and sweet potato were 9.8, 13.7, 7.8, 39.2 and 58.8 kg mm^{-1} ha^{-1} respectively. The net monetary benefits were in the order of watermelon, sweet potato, groundnut, maize and rice with 57.7, 43.3, 38.5, 18.9 and 14.4 RMB mm^{-1} ha^{-1} respectively, where as the net monetary advantage per unit area were in the order of watermelon, sweet potato, maize, rice and groundnut with 2800, 2250, 800, 550 and 300 RMB ha^{-1} respectively due to availability of water attributed to the water harvesting structures and irrigation facility created through pumping of river water to tank (Table 1). Among five crops, watermelon was most efficient and beneficial in terms of production and economics aspect followed by sweet potato, groundnut, maize and rice.

Table 1. Effect of watershed interventions on crop yields per unit of water conserved at Xiaoxincun watershed.

Crops	Net increase in yield (kg ha^{-1})	Yield per unit of water conserved* (kg mm^{-1} ha^{-1})	Net increased benefit (RMB ha^{-1})	Net benefit per unit of water conserved$^{\#}$ (RMB mm^{-1} ha^{-1})
Rice	500	9.8	550	14.4
Maize	700	13.7	800	18.9
Groundnut	400	7.8	300	38.5
Watermelon	2000	39.2	2800	57.7
Sweet potato	3000	58.8	2250	43.3

* Yield per unit of water conserved (kg ha^{-1} mm^{-1}) = Net increase in yield (kg ha^{-1}) / water conserved (mm)
$^{\#}$ **Net benefit per unit of water conserved (RMB ha^{-1} mm^{-1}) =Net benefit (RMB ha^{-1}) / water conserved (mm)**

SP Wani, TK Sreedevi, R Sudi, Vamsidhar Reddy,
Yin Dixin and Zhong Li

Output target 2011 9.3.2 Quantification of nutrients recycled by tank silt and its impact on soil and crop - A Pilot Study in Warangal district of Andhra Pradesh, India

Progress/Results:
Tanks have been an integral part of rural life in India traditionally. However, with decreasing collective action by the community, inappropriate soil and water management practices adopted by the farmers, encroachments of tanks and waterway by the individuals resulted in neglect of the tanks in villages. Good practices such as desilting and application of silt to agricultural fields have been abandoned. Continued mining by crops and reduced application of organic manures have resulted in deficiency of several nutrients particularly that of micronutrients. ICRISAT in association with Modern Architects of Rural India (MARI), an NGO conducted a pilot project and quantified major and micro-nutrients present in the tank silt and also its impact on soil health and crop yields.

The depth of silt in 12 tanks de-silted ranged from 1.2 m to 3.0 m. The pH of the tank silt ranged from 6.5 to 8.5, while the organic carbon content was found to be low (0.5% to 0.8%). The available N content of tank silt ranged from 328 to 748 mg kg^{-1}, available P 5 to 35 mg kg^{-1} and K 271 to 522 mg kg^{-1}. Similarly, available S ranged from 12 to 30 mg kg^{-1} zinc from1.2 to 5.6 mg kg^{-1} and boron 0.4 to 0.8 mg kg^{-1}

of silt. Microbial population was found to be low and it could be due to excessive use of pesticides for cash crops like cotton and chilli grown in the catchment area. Textural analysis indicated 70 to 80% clay, while the silt ranged from 15 to 25%. Addition of tank silt at 50, 100, 150 and 375 tractor loads per hectare improved the available water content by 0.002, 0.007, 0.012 and 0.032 g g^{-1} of soil, respectively in the plough layer and enhanced the tolerance of rain-fed crops to moisture stress by three to five days. The farmers could recover the investment made on transport of the silt through increased net profit in cotton and chilli compared to turmeric and maize. Further, the saving on pesticides alone was in the tune of Rs. 2500 ha^{-1} in cotton and chilli crops, which has indirect beneficial impact on the ecosystem. De-silting was found to be an economically viable activity both in terms of farmers' and project's perspective to create more storage capacity as well as to return the silt back to the fields. De-silting activity needs greater support from the government and non-governmental agencies for achieving multiple outputs like employment generation for landless, rejuvenating of the tanks and for enhanced and sustainable productivity of dryland crops.

<div align="right">Mohammed Osman, SP Wani, C Vineela and R Murali</div>

Output target 2008 9.3.1 At least 2 technical options provided for intensifying and diversifying production systems in low and high potential environments

Achievement of Output Target:
33%
2009/10 season and 2010/11 seasons will complete work by June 11.

Participating countries:
Zimbabwe

Participating partners:
NARES (Agritex), smallholder farmers

Progress/Results:
In Phase II of the Protracted Relief Programme (PRP) for Zimbabwe, ICRISAT has been tasked with technical evaluation of specific management options for inclusion in the conservation farming practices to be promoted to vulnerable households by NGO's. These include staggered alignment of planting basins to increase water capture, optimal spatial and temporal planting configurations for including legumes in the planting basin technology and general agronomic evaluation of conservation tillage systems in raising crop productivity and water use efficiency. It should be noted that the staggered basin technology emanates from farmer feedback received during Phase I of the PRP. In 2008/09, ICRISAT conducted about 160 on-farm trails with farmers and Agritex officers to evaluate the technology options. This work was complemented with on-station experimentation. Key results of the first season of studies show: (i) intercropping the planting basins with cowpea had no effect on maize yield compared to sole maize, but intercropped cowpea yields were reduced by about 30%. However these results were influenced by the imposed lag in cowpea sowing dates and farmers suggested that the lag in planting cowpea should be reduced from 28 to 14 days. (ii) for on-farm trials, staggered basins gave a 20% increase in sorghum yields compared to in-line basins when the slope was greater than 2%, but no increase on flat lands. On-station results showed no difference in grain yield or soil water balance between staggered and in-line basins, but this result was influenced by poor crop establishment across plots. (iii) Conventional-tilled plots gave higher maize grain yields and higher soil water contents over 2 seasons compared to conservation farming tillage systems (basins and ripper) in on-station trials. Weed biomass was higher on the conservation tillage plots and largely explains these results. The experimentation will continue in 2009/10 season.

Special Project Funding:
Protracted Relief Programme in Zimbabwe (DFID is the donor)

<div align="right">John Dimes</div>

Output target 2008 9.3.2 Impact pathways approach applied in ICRISAT planning and M&E process for enhancing relevance of R&D interventions in the SAT

Achievement of Output Target:
100% for Zimbabwe

Participating countries:
Zimbabwe

Participating partners:
NARES (Agritex) and NGO's (CAFOD, CARE, CRS, Oxfam GB, SCUK and WVI

Progress/Results:
Since 2004, the Protracted Relief Program (PRP) through various NGOs has been actively involved in distributing fertilizer to vulnerable farmers to help re-establish farming operations These fertilizer distribution programs have been complimented by training on reduced fertilizer application rates, otherwise known as micro dosing. An evaluation study was conducted to assess the level of farmer knowledge and factors affecting the adoption of micro dosing technology. The study covered 12 districts; Binga, Hwange, Mangwe, Matobo, Tsholotsho, Insiza, Zvishavane, Chivi, Zaka, Chipinge, Mwenezi, and Mutare. Two wards were selected per district. 10 farmers who received fertilizer and micro dosing training were randomly selected per ward.

Three quarters of the farmers interviewed had more than 10 years experience in farming and yet by 1998 only 20% of these farmers had experience in using fertilizer. Close to 50% of the respondents started applying fertilizer to the field crops within the last five years. This coincides with the onset of free fertilizer distribution by NGOs. Close to two-thirds of the farmers frequently applied fertilizer since they adopted the micro dosing practice. However, the consistency in fertilizer use remains variable among recipient farmers with about 19% of the farmers in the survey rarely apply fertilizer to their crops, the majority citing fertilizer costs and availability as the main constraints to usage.

The majority of farmers (53.7%) received training on fertilizer use and microdosing directly from NGOs, who in most cases provided relief fertilizer packs. Local AGRITEX staff also actively participated in trainings, accounting for 39.7% of farmers trained. The involvement of

Lead Farmers in the promotion of microdosing is still limited, with only 6.4% of farmers receiving advice from Lead Farmers. Microdosing training was conducted by agencies at varying periods with 43% of the respondents claiming to having been trained before November, the onset of the planting season. There are concerns on whether this was too early in the season, given top-dressing normally takes place in January. Distribution of pamphlets and posters to complement training on micro dosing is still limited, with only 29.4%, and 14.9% of the farmers having seen pamphlets and posters respectively. The majority of the farmers (84.7%) used the recommended application method of top dressing with either bottle cap (50.2%) or teaspoon (31.9%).

Adoption of micro dosing practice has been influenced by the provision of relief fertilizer packs and associated training by NGOs and AGRITEX. There is still room for improvement in micro dosing promotion as some farmers were unclear about efficient fertilizer use and application methods. Opportunities for improvement include improved extension, continued research, improved market access, and pro-active farmer organizations addressing farmers' constraints.

Special Project Funding:
Protracted Relief Programme in Zimbabwe (DFID is the donor)

John Dimes

Output target 2009 9.3.1a Capacity building of NARES partners to implement improved NRM approaches, including use of simulation models, for intensifying and diversifying cropping systems in low and high potential environments undertaken.

Achievement of Output Target:
100%

Participating Countries:
India and USA

Participating Partners:
India and USA

Special Project Funding:
Watershed projects supported by the Government of Karnataka, India, Ministry of Land Resources, Government of India and the Indo-US AKI project, University of Florida.

Progress/Results:
- To enhance the awareness amongst senior and middle level watershed development staff from different states in India, a capacity building program about the new integrated watershed development program and the common guidelines for implementing the watershed programs in India to enhance productivity and rural livelihoods was conducted from 21-27 December 2009 at the ICRISAT center. Various issues in making these guidelines operational were discussed and solutions suggested. About 36 officers from 18 states of India supported by the faculty from India, University of Florida and ICRISAT participated in the program.
- A team building workshop was organized on 2nd May 2009 in Bengaluru, to familiarize all stake holders regarding productivity enhances and natural resources management approaches adopted in the Bhoo Chetana project of Karnataka. The participants included nodal officers in the Commissionrates of Agriculture and Water Development Department, all Joint Directors of Agriculture (JDA), Assistant Directors of Agriculture (ADAs) and District Watershed Development Officers (DWDOs) from the districts along with ICRISAT Scientists and Scientific officers and Resident Research Technicians of the respective districts. The mission staffs were exposed to goal of the mission-mode project and objectives of the project; planning, co-ordination and implementation arrangements among stake holders were discussed and mechanism for monitoring the progress of implementation was decided. Trainings were organized in three stages considering area of operation as 1. District-level training; 2. Taluk-level training; and 3. Cluster-Village level training. In six districts 19 training programs were held and 1128 offices were trained in implementing the project plans. These trained staff further trained the stakeholders at the taluk and village level.
- ICRISAT, ICASA and University of Florida conducted a short course on "Cropping Systems Models: Applications in land Resource Management" from 12-16 October, 2009 at ICRISAT center Patancheru. The course focused on applications of crop models for managing water and nutrients in rainfed production systems and adaptation to climate change. Both the basic aspects of crop modeling and practical aspects of using the DSSAT v4.5 software and management of cropping systems were covered. About 27 collaborating scientists attended the training program.

Output target 2009 9.3.2a The water productivity of at least three strategic crops, under improved water management systems quantified, for intensifying and improving the economic use of water in low and high potential environments, and widely disseminated in WCA and ESA regions

Achievement of Output Target:
100%

Participating Countries:
Burkina Faso, Ghana

Participating Partners:
INERA – CNRST (Burkina Faso); SARI – CSIR (Ghana); SAFGRAD – (African Union); TSBF-CIAT (Kenya); ZEF, Center for Development Research – (Bonn, Germany)

Progress/Results:
Outputs are documented in CPWF PN5 funded Project Completion Report "Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin".

Special Project Funding:
Challenge Program Water and Food

D Fatondji

Output Activity 9.3.2b At least six water management technologies/practices for strategic crops, adoptable by smallholder farmers in ESA are identified and their returns to investment quantified

Achievement of Output Target:
100%

Participating Countries:
23 countries in Eastern and Southern Africa. These being: Angola, Botswana, Burundi, Comoros, Democratic Republic of Congo (DRC) Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Seychelles, South Africa, Sudan, Swaziland, United Republic of Tanzania, Uganda, Zambia and Zimbabwe

Participating Partners:
ICRISAT and IFAD

Progress/Results:
Six reports for case studies in Ethiopia, Kenya, Madagascar, Malawi, Rwanda, Tanzania entitled *"Agricultural Water Management Interventions with Proven Returns to Investment under Smallholder Systems'* completed. Regional Synthesis report of the findings of Technical/Socio Economic studies also completed.

Special Project Funding:
None

<div align="right">Bancy Mati</div>

Output target 2010 9.3.1 Report on rural livelihoods in the context of relief programs in Zimbabwe

Achievement of Output Target:
75%
Project end-date is June 2011

Participating Countries:
Zimbabwe

Participating Partners:
NARES (Agritex) and NGO's (CAFOD, CARE, CRS, Oxfam GB, SCUK, WVI, CTDT, RoL, FACHIG,Concern, CADEC, Christian Care, ORAP, ACF)

Progress/Results:
A survey study was conducted in March-May 2009 to assess trends in adoption of conservation farming (CF) technology amongst small holder farmers in Zimbabwe. A total of 15 districts were sampled in which NGOs have been promoting CF to vulnerable households for at least three years. The study employed a panel approach where the same farmers that were interviewed in previous surveys since 2007/08 season were re- interviewed, with objective of assessing CF impacts across time. A total of 416 households were interviewed.

Different CF components are being practiced at different levels. Winter weeding remains a challenge due to labour and time constraints, with 63 % of farmers practicing it. Application of residues is still limited (56%), whereas fertilizer application is largely dependent on NGO input support. A total of 11% of the farmers stopped practising CF during the 2008/09 cropping season and these were all from wards where NGO's had halted the input distribution. The NGOs relief programs were the main source of inputs with a total of 45.7 % of farmers receiving inputs from NGOs. Input support was however limited and farmers also relied on seed from previous harvests kept in their own stock. Market sources of seed were limited, largely due to the unfavorable market conditions that prevailed during the course of the 2008/09 season. The greater proportion of total CF area was planted to maize (82%), even in drier areas where maize production is risky. Farmers prefer maize because it is the staple crop, and are even reluctant to rotate with legumes.

As expected, farmers had higher yields on CF plots than on non CF plots. Average CF maize yield was 1664 kg/ha compared to 997 kg/ha for non CF across all 15 districts. In most instances CF plots were better managed, ensuring timely planting, weeding, and appropriate application of fertilizer. However, the contribution of CF to total household food security requirements was limited due to small CF plot sizes. Only three out of the 15 survey districts had CF cereal production contributing more than 50% to total cereal production. Labor still remains a major challenge limiting the expansion of CF area, with some farmers perceiving CF as a hard way of farming. For example, labor data collected across districts shows that the main components of the CF package representing additional labor inputs (basin digging, residue management, winter weeding) amounts to a 30% increase in labor demand relative to normal crop husbandry. CF plot size is limited by access to inputs and the increased labour requirements associated with larger CF plots. Male headed households tend to increase plot size over time more than female headed households as the latter are likely to face more serious labour constraints.

Research should continue to explore different recommendations for different areas as farmers face dynamic agro- ecological and soil environments. It is risky to promote CF as a blanket technology across different regions. Rather it should be promoted as a flexible and adaptable package to reflect the environmental and socioeconomic conditions of different households. Most extension is being done by NGOs, with AGRITEX's role being limited, mostly due to lack of resources. AGRITEX should however play a leading role in spearheading CF uptake and there is need to continue capacity building within AGRITEX and NGOs to sustain CF uptake. There is also need to pursue alternative relief input distribution programs, with the voucher based system being an option. Farmers need to be linked to input markets such as commercial agro-dealers and local retail outlets.

Special Project Funding:
Protracted Relief Programme in Zimbabwe (DFID is the donor), European Union (EU) and European Commission Humanitarian Aid Office (ECHO)

<div align="right">John Dimes</div>

Output 9.4: Affordable and sustainable integrated crop management o p t i o n s (IPM and IDM) developed and promoted w i t h associated capacity building in collaboration with NARES partners i n Africa and Asia

Output target 2011

Achievement of Output Target:
60%

Participating Countries:
India

Participating Partners:
JNKVV, Jabalpur and IGAU, Raipur; BAIF, BYPASS, DEEP

Special Project Funding:
National Food Security Mission (NFSM), Government of India; SRTT; SDTT; GoI

Output target 2011 9.4.1 Farmers participatory IDM (as a major component of ICM) for the identification and inclusion of legumes in the rice and or wheat cropping systems evaluated and promoted

Progress/Results:
Chickpea in Rainfed rice fallow lands of India: Overall objective of the project is "Harnessing Improved Production and Protection Technology (IPPPT) in the rainfed rice fallow lands (RRFLs) of Chhattisgarh and Madhya Pradesh". Under this project, three farmer's participatory activities 1) farmers participatory varietal selection (PVS), 2) IPPPT demonstrations, and 3) village level seed system (VLSS) were conducted in collaboration with NARS partners (JNKVV, RGKV) in the targeted villages in eight districts in Chhattisgarh and Madhya Pradesh in 2008-09 crop season. Location-specific components of IPPPT including IDM, IPM and INM were standardized.

In the PVS trials, the chickpea variety JG 74 recorded highest grain yield both in Chhattisgarh (2.38 t ha^{-1}) and Madhya Pradesh (2.02 t ha^{-1}). The variety was preferred by farmers not only because of its higher yield but also because of its desirable grain size. Total 592 farmer's participatory IPPPT demonstrations were conduced with success rate of 90% in Chhattisgarh and 100% in Madhya Pradesh. IPPPT gave 34-60% yield advantage across locations as compared to local farmer practices. Among all the varieties, JG 74 and JG 11 were preferred by the farmers.

In the village level seed system (VLSS), total seed produced was 15.23 t from 13.28 ha both from Chhattisgarh and Madhya Pradesh. This seed will be sufficient to cover 203.06 ha of additional area during 2009-10 crop season. Approximately 20 % of the total chickpea production in IPPPT demonstrations was kept as seed by the participating farmers at individual house hold levels. Hence total seed produced and stored from VLSS and IPPPT at village and district level is 31.89t in Chhattisgarh and 27.10 t in Madhya Pradesh and is sufficient to cover 425.2 ha in Chhattisgarh and 361.33 ha in Madhya Pradesh during 2009-10 season.

IPPPT package was highly profitable and cost effective. Net return by using IPPPT was 110% in Chhattisgarh and 131% in Madhya Pradesh higher than the farmer practices.

Capacity building

i)   IPPPT orientation program to farmers was conducted in five villages of Chhattisgarh and Madhya Pradesh each during 2008-09 crop season to educate farmers on major production constraints and their management practices. Total 398 farmers participated in training in targeted villages.
ii) Conducted two days orientation program to eight Research Associates as trainer's training posted in Chhattisgarh and Madhya Pradesh on "Improved pulse production and protection technology for growing chickpea in RRFL" at ICRISAT, Patancheru, Hyderabad.
iii) Delivered lecture to 50 Agricultural Officers/Assistant Directors of Agriculture on "improved production technology of pulses (legume) crops" including IPM/IDM.

<div align="right">Suresh Pande</div>

Output target 2011 9.4.1 Capacity building of NARS in IPM through watershed programs

Progress/Results:

- During this year 125 farmers (from Rajasthan and Madhya Pradesh), 35 NGO's (Medak district) and 8 researchers (Chhattisgarh and Madhya Pradesh) from various watersheds had an opportunity to interact with IPM team during their visits to ICRISAT. These meetings were mainly concentrated on the integrated pest management aspects with emphasis on eco-friendly approaches.
- Under the activity of "Bhuchetana" project in Karnataka IPM team involved in the capacity building of 90 NARS researchers and 1130 farmers of Kolar district (Mulbagal, Bangarpet and Kolar taluks) covering 256 villages.

<div align="right">GV Ranga Rao and Rameshwara Rao</div>

Output 5: Affordable and c r o p - l i v e s t o c k management o p t i o n s developed and promoted w i t h associated capacity building in collaboration with NARES partners i n Africa and Asia

Output target 2010

Achievement of Output Target:
70%

Participating Countries:
China, Ethiopia, Zimbabwe; Mozambique, Namibia,

Participating Partners:
GAAS, Guizhou; YAAS, Yunnan province, CAAS; ILRI Ethiopia, IWMI Ethiopia, NARS Zimbabwe; ILRI, Kenya, Mozambique, India; NARS: Namibia, Mozambique and Zimbabwe. Universities: National university of science and Technology, NUST, Zimbabwe, NGOs: Namibia: Namibian National Farmers Association; Zimbabwe: SNV, ORAP, Practical Action

Special Project Funding:
Asian Development Bank (ADB), Manila, Philippines; IMWI, EU-ORAP; EU thru ICART, EU-ORAP, IWMI, SLP

Output target 2010 9.5.1 Impact of watershed development on Forage production and livestock development in China:

Progress/Results:
Due to increased water availability, the area under the forage production and its yield has increased substantially at Lucheba benchmark watershed in China. From very small area of 8.4 ha in 2003 to 15.7 ha during 2004-05 reflects an increase of about 100% in two years. Substantial increase in net monetary returns, yields and RWUE were recorded during 2003-2005.

The forage production has enhanced the livestock development activities in the watershed. It is quite evident from the data reported by Animal Husbandry Office of Lucheba watershed (Table 1). The increase in the number of animals shown in the Table 1 is the population at the end of year, but in some cases like with pigs, baby pigs would be sold in two months and fat pigs in five months, which are not included in the below Table 1.

Table 1. Livestock development at Lucheba watershed, 2003-2005.

Livestock	Livestock population (no.)		Increase (%)
	2003	**2005**	
Cattle	195	217	11.2
Pigs	512	1017	98.6
Chicken	738	1589	115.3
Duck	251	301	19.9
Goose	120	136	13.3

(Source: Animal Husbandry Office, Tianlong Township)

Biogas production units: The substantial increase in the animal population promoted the biogas plants for daily energy need for cooking and lighting in the watershed. The biogas provided the safe, clean and low-cost energy while protecting the forest for their fuel need and farm yard manure requirement on the farm through environment-friendly disposal of animal wasters. Biogas plants encouraged farmers to use cattle and pig litter, night soil and rural wastes for dependable alternate source of energy, besides improving quality of manure. The survey revealed that during 2003 to 2005, total 76 biogas plants were constructed in the watershed and presently about 70% of households use biogas energy for domestic use in the watershed. A biogas tank of 8 m^3 can provide enough energy for a family of 6 with litter of 4 pigs. On an average farmers use to spend about 690 RMB per annum per household (at the rate of 2.5 – 3.0 ton coal use per year costing about 250 RMB per ton) on purchase of coal, by installing the biogas farmers can save this money on coal in addition to firewood.

<div align="right">SP Wani, TK Sreedevi, R Sudi, Vamsidhar Reddy,
Yin Dixin and Zhong Li</div>

Output target 2010 9.5.1 Assessment of drivers for change in water use at the landscape scale including Water Governance profiles in study sites (Ethiopia and Zimbabwe) and an assessment of their effectiveness for integrated water management in crop livestock systems

Progress/Results:
Initial work in the project was characterized by the development of six Masters degree proposals and one PhD proposal. These projects explore the characteristics and dynamics of crop-livestock systems in Zimbabwe and will define the fundamentals of livestock water productivity. Various papers are being prepared for a special journal edition to be published during 2010. Patricia Masikatis PhD is progressing very well and first drafts of the first four chapters have been completed. This project will be completed in 2010.

Titles include:
P Masikati, J Hargreaves, K Descheemaeker, A van Rooyen, S Homann-Kee Tui, G Sisitho, M Mativavarira. Potential contribution of maize stover and forage legumes to dry season cattle feed in the semi-arid tropics.

Feed shortages during the dry season are one of the major causes of low livestock productivity in semi-arid areas. Crop residues especially from cereal crops constitute about 10 to 74% of total livestock feed requirements. Maize production simulations were done using APSIM to evaluate the potential maize stover production under three fertility treatments namely farmer practice (FP), micro-dose (MD), recommended (RC) and under maize-mucuna rotations. In addition the potential contribution to daily dry matter and crude protein requirements during a 90 day critical feed shortage period was evaluated. Results obtained show that average stover production under conventional farmer practices can only constitute up to 20% of daily dry matter requirements when treated with urea. Stover produced under MD and RC practices can constitute up to 40% and 60% respectively, while stover and mucuna mixture can constitute more than 60% of daily dry matter and crude protein requirements. Maize stover had 6.22% CP while stover and mucuna mixture had 9.45% CP. Maize stover has the potential to contribute substantially to livestock feed required in terms of quantity and quality with soil fertility amendments, stover treatment and mixing with forage legumes.

Daniel Nkomboni, André van Rooyen, Sabine Homann-Kee Tui, Givious Sisito. Assessing the impact of mortality and fertility on cattle productivity in mixed smallholder farming systems through demographic simulation modeling.

The consumption of animal products is growing at a rate higher than that of the human population. Although this presents the opportunity for small holder farmers to improve their livelihoods through livestock keeping, productivity remains low. High mortality and low fertility mainly caused by feed and health related factors are the reasons of low cattle productivity in semi-arid Zimbabwe. Mortality is an unproductive as cattle that die, die with the feed that they eat. As most of the rain water is used for feed production, mortality wastes it and lowers livestock water productivity (LWP). The objectives of the study were to characterize the existing situation in terms of feed, health

and herd size and assess the impact of mortality and fertility on cattle production. The data were collected using household surveys and participatory rural appraisals (PRAs). Farmers were grouped into poor and better-off cattle keepers' wealth groups. A simulation modeling approach was applied to evaluate to what extent livestock production and LWP can be improved by reducing mortality and increasing fertility in the wealth groups. The DynMod model was used for the simulation animal population dynamics and the number of animals produced per year. Most farmers (64%) grazed their crop residues in situ. None of the farmers grew improved legumes and cereal forages for animal feeding. However there were low cattle deaths due to feed shortages. The highest cause of mortality was diseases (84%), whilst plant poisoning claimed 7% of the animals. Mortality was relatively high amongst the different classes of stock with an overall mortality rate of 0.17. Fertility was low with parturition rate at 0.48 on average. The projection of the current system showed a decline in animal numbers for the poor and better-off farmers. Better off farmers cattle mortality rate in absolute terms was higher than the poor farmers' cattle. Complex management with larger herds could be the reason for this trend. Reducing the mortality while increasing parturition rates improved cattle production for both poor cattle farmers and better-off cattle farmers. Despite the introduction of droughts after every 5years and increased off-take the simulated scenarios indicated an increased population. If a maximum number of cattle is set above which excess animals are sold, this does not increase feed requirements in the long term but stabilize the situation and as a result there is effective utilization of feed resources. Addressing livestock management affects cattle (livestock) production as well as LWP. Improved feeding and health technologies considerably reduce mortality and improve livestock productivity increasing the outputs (animal products, draft power, income) and food security.

TS Senda, S Homann-Keetui, JLN Sikosana, A van Rooyen, G Sisito. Livestock Water Productivity and Gender in Nkayi district of Zimbabwe a semi-arid area with mixed crop-livestock system, to be submitted to an international journal.

In crop-livestock systems of southern Africa water is becoming a scarce resource, mainly driven by increasing human populations. Climate change models predict aggravated trends. This situation calls for interventions that improve livestock water productivity (LWP), particularly reducing mortality rates through improved livestock health management and feeding. This paper describes the current livelihood situation of farmers in Nkayi district and highlights gender implications for interventions in crop and livestock production. Nkayi district is a typical area where most farmers are resource poor and human population densities are relatively high. Farmers in Nkayi depend on crop and livestock production as the most important livelihood activities. The influence of women in livestock production is substantial, considering that 40% of the households are female headed and livestock as well as croplands are similarly distributed between male and female headed households. Within many households women contribute to decision making, implementation and management, most often jointly with men. Farmers invest little in improved livestock management, mainly because they lack relevant knowledge and access to necessary inputs. Collective action is also poorly developed as very few farmers are members in farmers associations. The study confirms a great potential to improve LWP in Nkayi through improved livestock health and feeding management. Interventions that acknowledge the important role of women in livestock production and management (livestock health management and feeding) are more likely to improve LWP. They need to strengthen women's' capacities in livestock production and management and ensure that women have the full authority in decision making processes, with equal access to information and technologies. Strengthening the role of women in technology development can achieve greater impact on the resource poor farmers, and ensures that they benefit equally from improved LWP.

A Sibanda, Chirima A Homann – S Kee Tui A van Rooyen, D Nkomboni, G Sisito. Understanding user communities' perception of land use and land cover changes: Evidence from Nkayi District, Zimbabwe

The objective of this study was to investigate the user communities' understanding and interpretation of land use and land cover changes in their rangelands. It seeks to provide insights into how user communities perceive the current status of their rangelands, how they have changed over time and what the impacts of those changes are to their livestock and livelihoods. Through analysis of data on community perceptions collected through household surveys, participatory rural appraisals and participatory GIS methods, the paper shows that user communities in Nkayi, Zimbabwe are able to define the current status of their rangelands and how they have changed over time. The rangelands considered as separate resource units divided according to location, productivity, use and availability in space and time have undergone changes through reduction in area and conversion to other land uses (e.g. rangelands to croplands). Although the land use and land cover changes were considered to be widespread and multi-directional (both negative and positive) they did not cause widespread degradation. Most rangelands were considered to be in good to medium condition, with some moderately degraded. The changes resulted in loss of biodiversity in some areas, with a reduction in biomass quality and quantity, leading to dry season livestock feed shortages. However, when considered separately from other environmental factors (such as drought and disease outbreaks), the negative impacts of land use and land cover changes were considered to be low to moderate on livestock and moderate to high livelihoods. Both impacts were viewed as manageable through a number of adaptive herd management strategies. Not all land use and land cover changes were considered as negative, as some were viewed to be positive. Rangelands converted to croplands were not completely lost, but became important dual purpose land parcels fulfilling both household food security needs and dry season livestock feed requirements. Such land parcels were considered better managed as individual households utilizing them were prepared to invest in them (to soil fertility improvement, erosion control etc) to ensure food security. The importance of such lands increased as dry season feed sources and new strong informal institutions governing their use as rangelands emerged to guarantee security of tenure. The study shows that this was widely accepted as a moral right to survival, guided and justified by local institutions and unlikely to change in the foreseeable future. On the other hand institutions governing the use of common property rangelands decreased or weakened in their application. The study concludes that while this situation presents ecological challenges in communal rangelands, it offers opportunities to find innovative ways of utilizing croplands as the new frontier in the provision of dry season feed resources to smallholder farmers in highly variable environments.

Albert Chirima, André van Rooyen, Andrew Sibanda Land degradation: Evaluating land cover changes in Nkayi district; 1990 to 2009
In Zimbabwe land degradation is a major constraint to farmers particularly those in the semi arid areas of the southern region, in places such as Nkayi district. This paper looked at developing temporal land cover maps to estimate the rate and trends of land cover from 1990 to 2009. Multi-temporal images of LANDSAT TM and ETM⁺ scene p171r74 covering Nkayi district were analyzed in using GIS and Remote sensing software. Four main land cover types were observed and the changes that happened to them were also highlighted. Areas under pristine forest conditions covered more than half of the total area (57%) while cultivated land, deforested land and water bodies occupied 30%, 11%, and less than 0.31% respectively in 1990. However 49% of forested area was available by 2009, highlighting more than 43000 hectares of forest land lost. While areas under good forest conditions decreased, cultivated land and deforested land increased to 35% and 15% during the same period from 30% and 11% respectively in 1990. This means that 21000 hectares of land was cleared for cultivation since 1990 to 2009. The major causes of these changes were observed to be forest clearance for cultivation, and thereafter a sequence of processes take place.

M Mativavarira, A Van Rooyen, E Mwenje, J Dimes, JLN Sikosana, P Masikati Screening sweet sorghum for rainfall water use efficiency and fodder quality

In the 2007/08 season twenty sweet sorghum cultivars that included landraces and improved cultivars were screened as an alternative food and fodder crop for crop-livestock farmers in semi-arid tropics. The cultivars showed an adaptation to this environment as the grain yields of 1.03 – 4.53 t ha^{-1} were comparable to available sorghum varieties, but have significantly higher stover yields of 1.91 – 6.52 t ha^{-1}. These stover yields signify that sweet sorghum cultivars can bridge the large gap on fodder quantity supply and demand which is large in semi arid tropics. The landraces cultivars matured late and were much affected by terminal drying and have lower grain yields and grain water use efficiency. The grain and stover rainfall water use efficiency were significantly different among cultivars they range from 0.54 - 2.40 kg/m^3 ha^{-1}, and 1.40 – 3.96 kg/m^3 ha^{-1} respectively. The cultivars with higher stover water use efficiency like B24 and ICSV93046 had also high digestibility and metabolisable energy content. While cultivars with high grain water use efficiency had also significantly high leaf protein content. The leaves had significantly higher protein content, metabolisable energy and digestibility than the stems. Hence farmers can realize higher benefits by using leaves as their protein source for different livestock types and groups. The protein content which falls to below 20 g/kg DM in pastures in the dry season could be raised to 60 g/kg DM by supplementary dry season feeding with sweet sorghum crop residues. Among the cultivars, the landrace Matebele Sweet Stalk had the highest digestibility of 55.1 %, metabolisable energy of 8.31 mj/kg and leaf protein content of 39.8g/kg DM hence is more of fodder than grain cultivar. The protein content was comparable to cultivars with high grain water use efficiency these were, E 36-1, JJ 1041, PVK 802, ICSR 93034, ICSV 25263, SPV 1022 and SEREDO. Generally among the improved and land races sweet sorghum cultivars we have some cultivars with higher grain and stover water use efficiency , and fodder quality traits. Hence sweet sorghum cultivars have potential to improve livelihoods of crop-livestock farmers by providing food, and also enough feed for their livestock that meet their quantity and quality requirements.

<div align="right">Andre Van Rooyen and John Dimes</div>

Output target 2010 9.5.1 Environmental impacts of livestock intensification reduced during droughts and the dry season by developing and promoting alternative feed and fodder strategies in crop-livestock systems with associated capacity building

Progress/Results:
Diagnostics: Typology of crop-livestock systems in southern Africa

Main Results and Lessons Learnt
Livestock plays a major role in all the pilot sites of the three countries studied, contributing significantly to the livelihoods of house holds in the region. There are significant opportunities in the entire region to increase production and impact at household, local and regional levels.

- The main production constraint is the unacceptably high mortality rates observed in all the study areas. Therefore the first step to increase production and productivity would be to reduce mortality. Significant impact can be achieved through the reduction of mortality of both goats and cattle.
- Since mortality is primarily a function of animal husbandry, disease and dry season nutrition, entry points should focus on improved animal health and nutrition.

- In most areas, access to support services and inputs are major challenges. While government support services are often poor or lacking, the private sector has a major role to play and facilitating public private partnerships is critical to facilitate livestock development.
- Other production challenges include poor animal quality/breeds, inadequate access to information and inputs, and droughts.

Summary of PRA and household survey results from Gwanda District, Zimbabwe:

In October 2007 and in December 2007 and December 2008, household and PRA surveys were implemented in 6 villages in Nkwidze and Takaliyawa sale pen areas in Gwanda district. The household surveys provide quantitative data on socio-economics, livestock management and marketing data, and the qualitative PRA research tools comprise community resource mapping, wealth ranking, livelihoods and actor analysis. The surveys shed light onto the prevailing socio-economic situation, and identified farmers' current livelihood opportunities and constraints particularly in cattle production and marketing and goats to a lesser extent. This report highlights the key results to be fed into the Innovation Platform (IP) process at district level. It provides decision makers with priorities for future actions that will improve livestock production for better income and livelihoods of farmers in Gwanda.

Key challenges in goat production and marketing
Goat production and marketing is fairly well established in Gwanda, as compared to most other districts in Zimbabwe. Investments in goat infrastructure and services are however not adequate to make full use of the district's high potential. To improve livestock productivity and efficiency of the market systems, greater investments are required.

(a) Low goat productivity
High livestock mortalities are the key constraints to production in Gwanda. Farmers lose about 24% of their goats to mortality, more than double the total productive outflows though sales (6%) and slaughter (6%). Investments in management activities that reduce mortalities is the most efficient way for farmers who are interested in herd building and those that are more geared towards increasing off take. Farmers with few animals can build their herds and have more goats available to solve immediate needs (particularly in Nkwidze), while large herd owners can increase quantity and quality of their off takes for better margins (particularly in Takaliyawa). Only if sufficient animals of adequate quality can be supplied, the investments in market development can be sustained.

Key challenges to be addressed are:
Poverty: Many households have few livestock and often fail to sustain their own food provision. Farmers have a limited capacity to invest in improved production and management technologies as they had to focus on securing food needs. These households would benefit more from collective action (pooling resources together) where the cost per animal is reduced and affordable.

Poor rangeland management: Rangeland degradation affects the survival of livestock during dry seasons. The owners of small herds especially have limited access to alternative feeds. Coordinating the movements of many small herds is also challenging as these farmers often don't have the resources or capacity to improve rangeland management. Farmers with large herds need to find alternative feed sources or compensate for using larger proportions of the communal rangelands. Community-based institutions need to develop strong agreements

and regulations and enforcement of these decisions. Collective action needs to be strengthened, e.g. grazing committees, and traditional authorities need to enforce decisions and farmer associations or ZFU to be more proactive.

Poor goat nutrition: Although farmers are aware of the extent and impact of dry season feed shortages, they invest little in improving the nutrition of their livestock. Farmers use crop residues but they do not know how to improve their nutritional quality and do not have access to the necessary inputs. Low crop yields also imply that crop residues are not a reliable alternative. Farmers are reluctant to grow forages, as long as their fields can not sustain their own food supply. They also know little about alternative feed options. Such technologies would need consistent external support through training and demonstrations in order to be effective. Alternatively, farmers with larger herds can sell few animals to purchase stock feeds for the other animals. However, for this option to deliver the expected results, the market must offer appropriate prices for livestock, and stock feeds must be accessible.

Poor animal disease control, prevention and treatment: Farmers realize the importance of improved animal health management. They however often lack the knowledge to diagnose and treat the diseases and preventive measures were left to farmers' private initiatives. In most cases veterinary services, inputs and infrastructure are not functional or not accessible. Few farmers can afford to source inputs individually, mainly from Bulawayo town.

Poor collective action: A number of farmer associations are established at Takaliyawa even though their activities are limited. These associations need capacitated to act as agents that could drive efficient purchase of inputs, adoption of appropriate production technologies and marketing, and also control market situations.

Lack of financial assistance: Financial assistance is commonly given to support food security and this is related to crop production. The role of livestock is not reflected in the budgetary provisions, policy and other public sector support frameworks. Access to private sector support (loans) also does not exist. Without such financial support it will be very difficult for farmers to obtain feed and animal health inputs on an economically sustainable base.

(b) Poor market development
Farmers participate more in goat sales in areas with better developed markets. In Takaliyawa, where farmers also own larger herds, more than 50% of the farmers participate in goat sales and sell about 12% of their herds annually. The RDC is more engaged in maintaining market infrastructure and support market organization, and more traders attend the markets. In Nkwidze, where markets are poorly developed, farmers have smaller herds and depend on farmer-to-farmer sales. Most farmers sell during emergency situations when they desperately need the cash, and receive low prices for their goats.
Key challenges to be addressed are:

Low off-take: Farmers sell generally few animals, also those with large herds. This results in low market volumes and attracts only a few buyers. This has reduced competition among buyers and has negative influence on prices. This especially true for Nkwidze where no organized sales of goats exist.
Poor animal quality: Farmers sell animals of poor quality, which do not meet market requirements. This also contributes to few buyers attending the existing sales in Takaliyawa and prevents market development in general..

Lack of market information: Information about, quality requirements and volume of demand are not communicated to farmers. Farmers do not understand how market requirements influence prices. On the other hand, buyers also do not have access to information on animals for sale (quantity and quality).

Lack of grading system: Farmers do not understand the pricing mechanisms and are thus not able to make their own quality judgments. They determine prices according to their expected expenses, rather than technical criteria of the animals (e.g., age, body condition, health status, skin quality). Market actors like auctioneers need to use transparent weighing facilities (scale, body condition scoring) and a functional grading system needs to ensure objective price settings. Displaying goats helps farmers to compare the prices for goats.

Non-functional formal market channels: Goats were sold at poorly structured informal markets. Few buyers attended these markets and competition between buyers was therefore poor. Farmers accuse market players (auctioneer/traders/buyers) of colluding to keep prices low; farmers are in a weak position to influence prices and are forced to accept low prices.

Market infrastructure: Poor handling facilities had negative impact on goats. The animals were stressed in marketing situation, with a lack of feed, water and shade. Loading facilities are absent.

Market institutions: Functional market institutions were absent. The traditional authorities were very important in passing on information regarding to market events. The RDC was responsible in maintaining market facilities and organizing the sales. It was however beyond their capacity to control the livestock market operations, grading and price setting, and to ensure the supply of inputs such as vaccines, feeds and water. Furthermore, farmers did not understand the purpose of collecting levies and the reinvestment of levies was not transparent to them. Lack of collaboration between farmers, market players and input and service providers rendered the coordination of market operations inefficient.

Transport: Transport costs per goat were high, especially when markets were poorly organized or goats were bought at the farm gate. Buyers therefore transferred the high transport costs to farmers. Improved transport arrangements are beyond the scope of this baseline study and will be addressed by further efforts of value chain improvement.
Financial institutions: There is little support to farmers by finance institutions. Farmers lack awareness of the availability and role of such institutions. During times of hyperinflation such support systems were completely inefficient.

(c) Defining area-specific priorities for improved goat production and marketing through the IP
There is potential to enhance commercial goat production in Gwanda. Improved market access would benefit even those farmers who can only sell few animals. If they are paid fair prices for their livestock and if the market reward farmers for quality this will provide the incentives for improved management. It is expected that the goats offered for sale will be of better quality and more animals will enter the formal markets. Increased volumes of goats sold will reduce transaction costs, attract more buyers and make trade more efficient. Improved goat production will thereby contribute to increased food security and income amongst farmers in Gwanda.

What are the next steps in the IP process?
1. Select priority technologies and interventions, actors and support mechanisms
2. Define roles and responsibilities in driving this process further
3. Establish farmer associations for cooperative learning and input procurement
4. Link farmers with competent suppliers of information and inputs

What long-term benefits are expected for key actors?
Farmers will be better informed about the potential of cattle and goat production and market requirements, and supported in local technology development to increase their herds and produce sufficient animals for consumption and sale. Transparent price setting enhances their trust in market processes.
Regulators and public services will be able to reactivate interventions for more controlled land use and facilitate agricultural development (trainings, inputs and information).

Research and development organizations will be able to better target interventions to achieve greater impact from agricultural technology development and generate further support.
Market players will source animals more effectively (better organization of sales, better sale facilities, appropriate market channels, reduced transport costs, more consistent volumes and better animal quality).
Other private sector players will be able to start investing in agricultural production once certain market levels are established and more farmers participate in markets with consistent volumes and better animal quality.

Test and evaluate alternative product marketing systems and alternative input delivery systems
Main Results and Lessons Learnt
- While most farmers are highly dependent on generating cash from livestock sales, markets are very poorly developed in Mozambique and in Zimbabwe. Although markets in Namibia are much better developed, there are still challenges with the number of animals communities are able to supply to markets.
- Main challenges with regards to markets revolve around: access to information, i.e. when and where markets will take place; how prices are determined and what is required to obtain better prices.
- Auctions are a very good way of selling off livestock, but many farmers do not understand the system and are therefore hesitant to participate. In certain areas, livestock numbers do not warrant the time and effort for buyers to attend, resulting in low number of buyers resulting in reduced competition and therefore also reduced prices. Auctions were successfully established in Gwanda district in Zimbabwe – here, where buyers are solicited to attend, where the demand for goats are high and the supply from farmers are significant, the process has worked well.
- In areas where supply is limited, and therefore does not warrant many buyers to attend, the "permit system" as developed in Namibia is an excellent system to promote in countries with similar challenges. Here, buyers 'tender' their services through local authorities and advertises prices offered long before the day of sales. Prices are normally offered per kilogram of live carcass and segregated between different grades, ages, sex and whether animals are intact of castrated.
- From the analysis during this study its clear that inputs are notoriously limited and access is complicated through distances required to travel to inputs markets, lack of information and support services to communicate the required information. It is strongly recommended to facilitate the partnerships that will enable input suppliers to make their services (with regards to information and products) available at the point of sale. Preliminary information clearly illustrates farmer's preparedness to purchase inputs the point where animals are sold. By providing inputs at the market place, will create the incentive for further investments in production.
- Government support services are dwindling as a result of limited resources, lack of skilled and experienced personnel. It is envisaged that this role could be played by the private sector. Should small scale farmers engage in increased procurement of inputs, the private sector may just well provide these services where it is to their benefit, i.e. at the marketplace where potential buyers are concentrated and with cash in hand.

Work specifically involving feed and fodder technologies:

The working hypothesis of this work is that markets will ultimately drive the uptake of improved dry season feed technologies and improved feed systems. This is directly addressed three independent activities.

1. Within the livestock water productivity project (above) Mr Mativavarira's work assesses sweet sorghum varieties for use in Zimbabwe.

M Mativavarira, A Van Rooyen, E Mwenje, J Dimes, JLN Sikosana, P Masikati Screening sweet sorghum for rainfall water use efficiency and fodder quality

In the 2007/08 season twenty sweet sorghum cultivars that included landraces and improved cultivars were screened as an alternative food and fodder crop for crop-livestock farmers in semi-arid tropics. The cultivars showed an adaptation to this environment as the grain yields of 1.03 – 4.53 t ha^{-1} were comparable to available sorghum varieties, but have significantly higher stover yields of 1.91 – 6.52 t ha^{-1}. These stover yields signify that sweet sorghum cultivars can bridge the large gap on fodder quantity supply and demand which is large in semi arid tropics. The landraces cultivars matured late and were much affected by terminal drying and have lower grain yields and grain water use efficiency. The grain and stover rainfall water use efficiency were significantly different among cultivars they range from 0.54 - 2.40 kg/m^3 ha^{-1}, and 1.40 – 3.96 kg/m^3 ha^{-1} respectively. The cultivars with higher stover water use efficiency like B24 and ICSV93046 had also high digestibility and metabolisable energy content. While cultivars with high grain water use efficiency had also significantly high leaf protein content. The leaves had significantly higher protein content, metabolisable energy and digestibility than the stems. Hence farmers can realize higher benefits by using leaves as their protein source for different livestock types and groups. The protein content which falls to below 20 g/kg DM in pastures in the dry season could be raised to 60 g/kg DM by supplementary dry season feeding with sweet sorghum crop residues. Among the cultivars, the landrace Matebele Sweet Stalk had the highest digestibility of 55.1 %, metabolisable energy of 8.31 mj/kg and leaf protein content of 39.8g/kg DM hence is more of fodder than grain cultivar. The protein content was comparable to cultivars with high grain water use efficiency these were, E 36-1, JJ 1041, PVK 802, ICSR 93034,ICSV 25263, SPV 1022 and SEREDO. Generally among the improved and land races sweet sorghum cultivars we have some cultivars with higher grain and stover water use efficiency, and fodder quality traits. Hence sweet sorghum cultivars have potential to improve livelihoods of crop-livestock farmers by providing food, and also enough feed for their livestock that meet their quantity and quality requirements.

2. Within the EU/ORAP funded project on small stock market development, we have also engaged in training farmers and local extensions in adding value to crop residues. Almost 400 hundred farmers were trained in increasing the value of crop residues through urea treatment. Farmers pooled resources and cooperated in groups to ensure greater learning and benefits from labor inputs to dig pits and manage crop residues. All livestock was treated for internal and external parasites to have maximum impact. Animals were monitored during the process and farmers greatly appreciated this type of intervention. Following such animals to the market and to determine impact of improved dry season feed is the next step in this process.

	Number of pits	Number of farmers
Nkayi	29	100
Lupane	15	25
Tsholotsho	35	100
Gwanda	30	68
Beitbridge	18	22
Chivi	30	76

3. We are participating in the latest SLP project which has started during 2009: Regional case studies in crop residue management. Much of the research instruments have been developed and field will commence this season. The main research questions are as follows:

What determines the decisions about Crop Residue Use (inc. current crop management, agro-ecology, markets/institutions, resource endowments, dynamics etc.)?
- What is the current crop residue production (quantity and quality) and allocation in each system?
- How does access to market affect the decisions on production and allocation of crop residue?
- How do technology or management interventions (esp. outside livestock sector) impact on either CR availability or allocation/choices?
- How and why does current allocation vary among different household type (capital being a criterion for defining the types)?
- How does agro-ecology affect production and allocation?
- How does system intensification affect production and allocation?
- How do CR property rights vary by natural resource endowment (index rainfall + soil) and intensification (index population density + input use)? And how does this vary within and between regions?
- How has this allocation and production evolved over time?

What is the impact of those decisions on livelihood and environmental implications?
- How does CR use/allocation decision influence livelihoods?
- How does CR use/allocation decisions influence environment?
- How would additional CR (if available) be used?
- Does intensification lead to more efficient use of crop residues?
- What are the interactions of livelihood and environmental implications?

What are the technology, institutional and policy (TIP) options that would enhance livelihood and environmental benefits?

Andre Van Rooyen

MTP Project 10: **Virtual Academy for the Semi Arid Tropics in SAT Asia and WCA**

Project Coordinator: **V Balaji**

Summary:

During the year, the project activities focused on trials in semantic content management, with mobile telephony (with or without an innovative call-back arrangement), and with the use of open source, web-based GIS application's to make soil information easily accessible. Trials with video-conferencing were continued. The Agrocuri site part of the multi-center, multi-stakeholder initiative, was fully re-developed on open source platforms, and has been deployed on the web. This was tested with potential users in two different settings. The output targets have been fully achieved.

Output 10.1: ICT-mediated knowledge sharing strategy developed and implemented with partners and online, web-based repository of learning materials designed and developed in the public domain with appropriate capacity building

Output target 2009 10.1.1 Design of a Blend of Tools in Knowledge Sharing

During 2009, the crop knowledge models developed in the previous year were completely re-designed using a new mapping technique (Concept Maps) and with the participation of a large number of agricultural domain experts (particularly from plant breeding and agronomy). Concept Maps were initially tried in 2008. The advantage of Concept Map technique is its flexibility in effecting modifications through addition or deletion of concepts or change in relationships between them. A crop knowledge model represented visually as a concept map can be the equivalent of a formula and can be rendered in different languages for which a controlled, domain-specific thesaurus or vocabulary is available. Continuing from the previous year, the FAO AGROVOC has been used as the controlled vocabulary.

With inputs from the ICRISAT and the Indian Institute of Technology-Kanpur (IIT-K) a set of standardized relationships were drawn up. Approval of experts from specific disciplines such as genetics, agronomy, and entomology was sought in a series of workshops organized during January- March 2009. The relationships and concepts so finalized were then developed into concept maps. We have developed the final concept maps for all the mandate crops of ICRISAT. (In Figure 1A and 1B, the main concept map for chickpea and a section are provided). All the concept maps of ICRISAT mandate crops can be browsed at http://test2.icrisat.org.
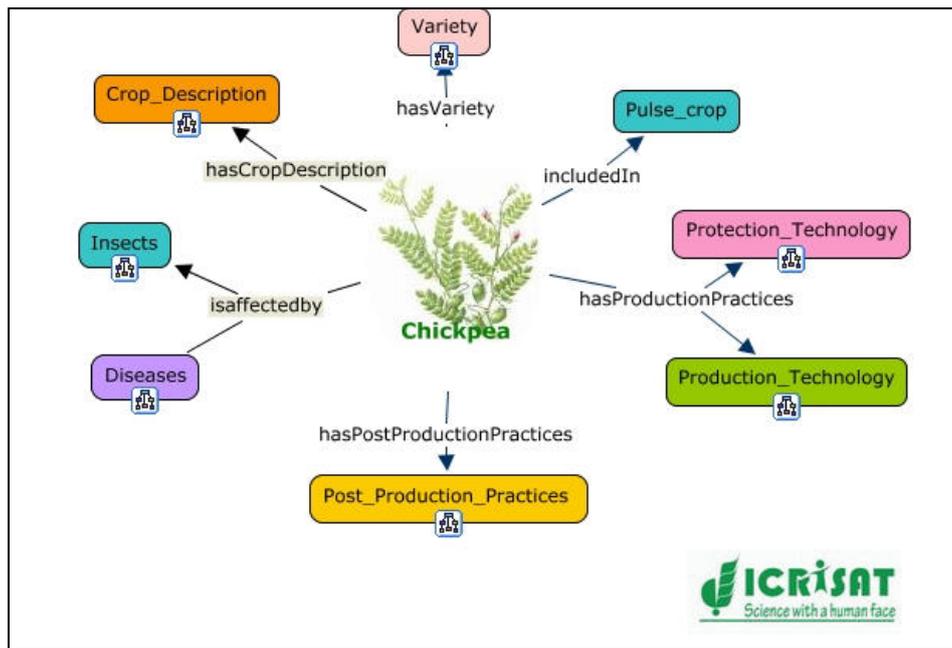
Figure 1A: A granularized concept map of Chickpea crop.
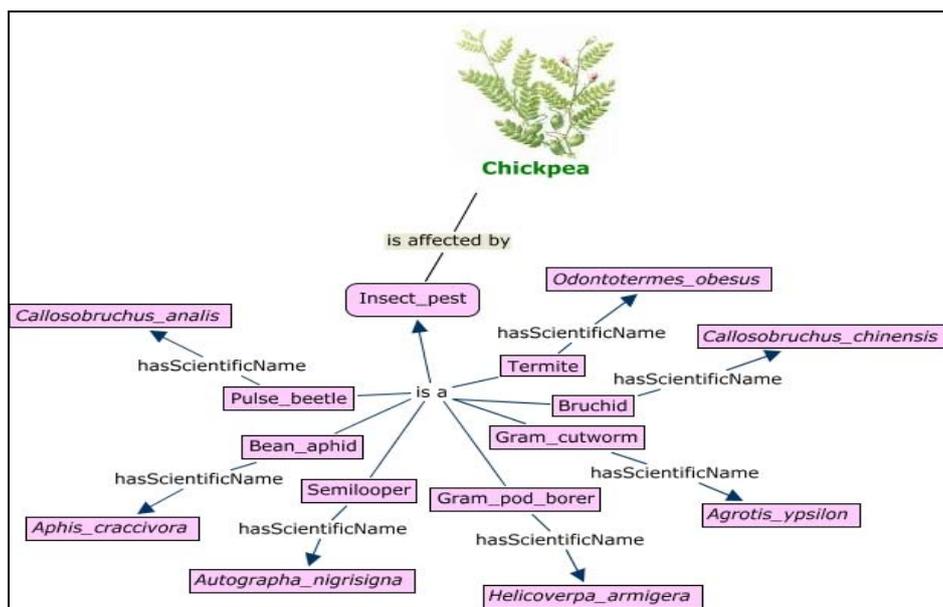
Figure 1B: a section of the concept map of Chickpea insect pests

These maps now underlie the content organization and platform, the Agropedia, which was engineered by the Indian Institute of Technology (http://agropedia.net).

This platform has several elements of Web 2.0 and ICRISAT has contributed significantly to its overall design. The Agropedia, built with concept maps of crops, allows for aggregation of content in any language in which the AGROVOC has been rendered (there are 19 languages as of December 2009) and can help locate through its search interface entries in any of those languages. In Figures 2A and 2B, a multi-lingual output for a search is displayed along with a glimpse of various Web 2.0 features of this site. Nine crops are covered on this site, including ICRISAT's five mandate crops; about 450 pages equivalent of material developed and validated on this project are covered in the Agropedia (total coverage in the current version is about 5000 pages equivalent). An analysis of digital information management literature globally showed that such models and a web site driven by them have been developed for the first time anywhere. ICRISAT, through this effort, has also catalysed the participation of two agricultural universities and several hundred national experts in content generation and validation on Agropedia site, while directly generating 860 person-days in training at the level of mid-level university faculty. On this effort, we have, through cross-sectoral partnerships involving ICT resource institutions and NARES organizations, brought together tools of Web 2.0 paradigm, such as Wikis and blogs, along with techniques from the sphere of semantic web.
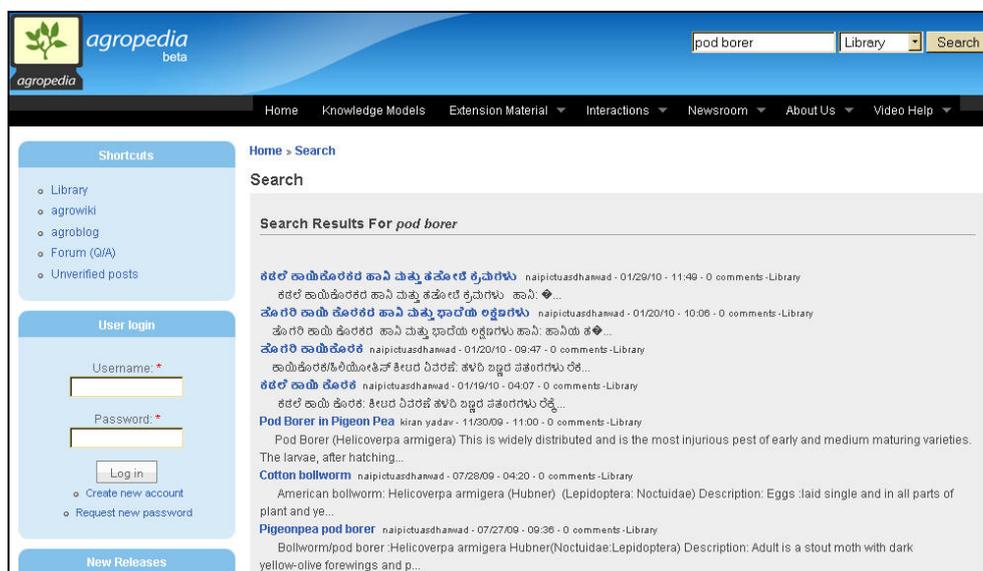
Figure 2A: A multi-lingual search output from AGROPEDIA

The data derived from the Google Analytics showed that the traffic to this site has consistently registered increases since launch in January 2009 (by 1100% over the year). As of late 2009, nearly 2000 expert users from over 35 countries had signed up.
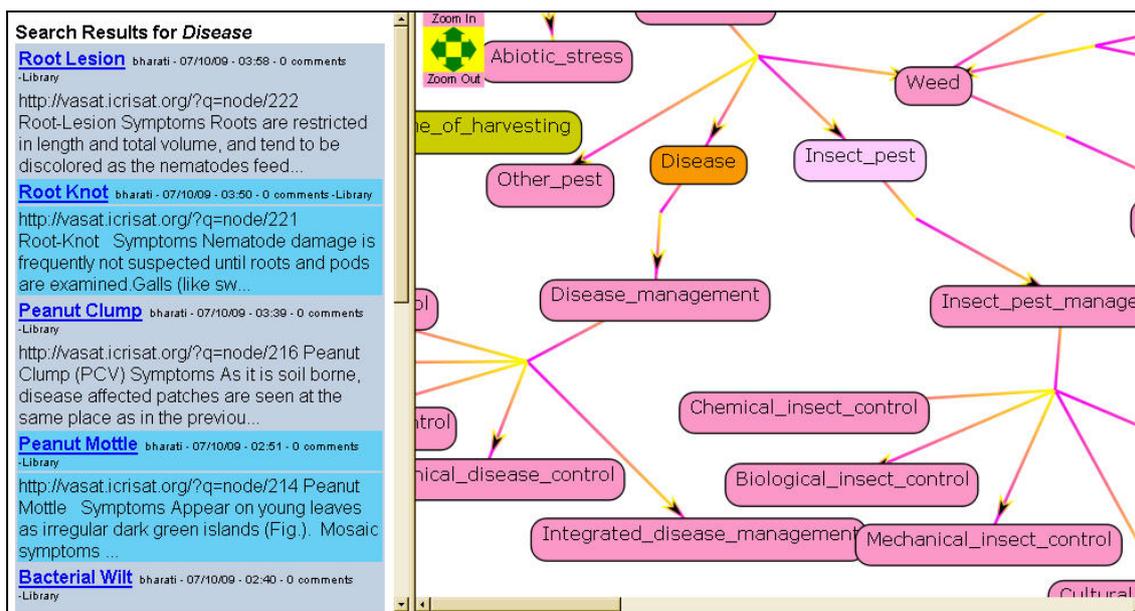
Figure 2B: Search executed through a map-like interface in AGROPEDIA

AGROVOC Revision

An important development during this year was the comprehensive revision of the AGROVOC in English which was completed by ICRISAT, thus making an important IPG even more current and effective. The purpose of such revision, as stated in the previous archival report, was to convert this multi-lingual thesaurus, a traditional term-based system, into a semantically structured ontology (a collection of concepts and relationships). See box 1 for an example to illustrate the power of ontology. This is now a base for the design and construction of a semantic web site such as the Agropedia, and further underlies efforts such as the AgroTags where a sub set of such semantically structured relations has been developed for use in tagging research publications (as contrasted to extension-oriented publications in VASAT sites) As of December 2009, the quantitative results of the revision process are:

Terms	Before revision (nos.)	After revision (nos.)
Broader Term (BT)	28625	33467
Narrower Term (NT)	28617	33467
Related Term (RT)	28219	45691
USE	19158	7738
Use For (UF)	17386	7738

The need for semantic relationships in agricultural information management

Much content is being made available online. Search engines work based on text-matching to retrieve results. This would not be quite useful in a knowledge-intensive field like agriculture. An example: when you search for the term "RICE" in any of the leading search engines, you would find an output distorted with lot of 'noise'. An effective way to streamline search results by introducing "knowledge" into the process is by way of using ontologies (similar to AGROVOC for agriculture). A typical entry in AGROVOC ontology contains

Rice *is a* Cereal
Rice *is also known as* Paddy
Rice *is affected by* Rice Blast
Rice *has cultivars* IR64, Basmathi etc.,

This "knowledge" which are present in the minds of subject matter experts are hard-coded into systems thereby making them Knowledge Repositories which can "understand" a user's query and produce very relevant results. Originally a thesaurus, AGROVOC is now being rendered into an online service to support new applications in agricultural informational Management.

Besides the content revision, a number of software applications for the AGROVOC concept server were developed or upgraded during the year. All these are developed using Open Source software (Java and MySQL with PHP)..

- An automatic topic map language converter was developed. This facilitates conversion of any agricultural topic map from any of the 19 languages supported by AGROVOC to any other language.
- Four languages viz., Russian, Hungarian, Czech and Korean were coded into AGROVOC master database.
- Modules for conversion of the AGROVOC SQL file to OWL (Ontology Web Language) snippets were created, these together with other codes designed and developed at Kasertsart University forms the basis of the AGROVOC Concept Server.

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Output target 2009 10.2 New approaches for enhanced access to ICRISAT IPG's developed, tested and shared with partners

10.2.1 Trials with delivering advisory information over mobile telephony

ICRISAT-facilitated consortium (of agricultural universities and ICT institutions) conducted trials on the use of mobile telephony in delivering production related advisory to farmers, with content coming from VASAT- Agropedia sites. During Jan- Dec 2009, a total of 17000 farmer's mobile numbers were brought into this arrangement, covering non-irrigated regions in four states of India. In this period, 678 unique messages were posted. The messages were generated based on local conditions as observed by the university extension personnel, or as noted by the community organizations. Just over 2.2 million messages were transacted. A survey of usefulness is in progress in four states (58 districts). For a duration of six months, during May-Nov 09, the Indian Institute of Technology-Bombay, conducted trials on an experimental platform called "Voice aAQUA". This platform enables short alert messages to be sent to a recipient who can call a number listed in the SMS/text to listen to the details.

Our analysis of usage revealed that re-playable voice message in general are preferred; the call-back is a clearer indication of recipient's interest in the information. In the trial period, a total of 641 "voice tips" were generated for 26473 farmers; the call back rate overall exceeded 80%. We noted that sending messages in non-Roman script tended to take more signal space, and cost three times as much as the same message in Roman characters. It is not yet clear if this would be on of the reasons for a preference for voice where the total cost is still half of non-Roman script message. The agriculture universities considered the voice platform as a major opportunity, and one of them formally reported the generation of 2500 digital voice tips that can quickly adapted and re-used. In general, it emerges that what is needed is a package that enables extension units to send out text or call-back messages without hassles, using a comprehensive knowledge base.

Use of Geo-spatial information techniques in visualizing soil nutrient information

The soils group in the GT-AES has a data set covering 12000 locations in the state of Karnataka in India. The data set for each point contains information on micro-nutrients as well as carbon, phosphorous and potassium. The GT-AES led a trial in rendering this information via the web, with a VASAT partner, the Indian Institute of IT and Management. The soil data set was fully geo-referenced by the GT-AES scientists, and the partner used the Open Web GIS platform to make it available via the web. For this trail data set of 2000 points was used. The map display was designed to include multiple layers (such as administrative boundaries, weather forecast for the locations, physical relief etc). on to this, the soil science experts introduced thresholds to determine deficiency for each nutrient. The map is thus able to give a direct display of deficiency of a nutrient over an area (Web URL: http://www.akmindia.in/agrogis/dhwd1/index.php). This is now being extended to cover the entire state of Karnataka, and serves as an example of the way Open Source Web GIS technology can be used to provide a highly effective solution in map-publishing (Figure 3 below).
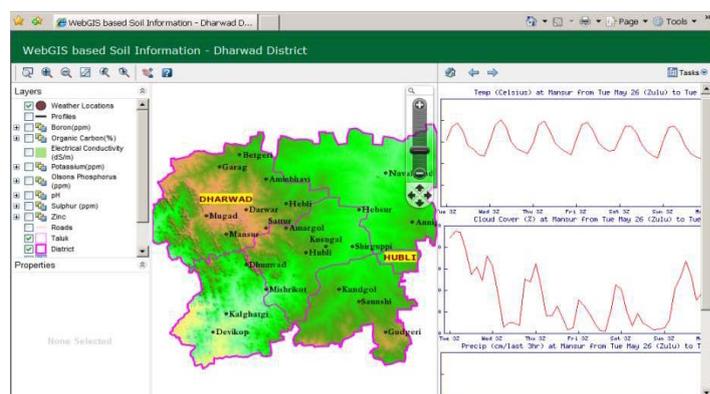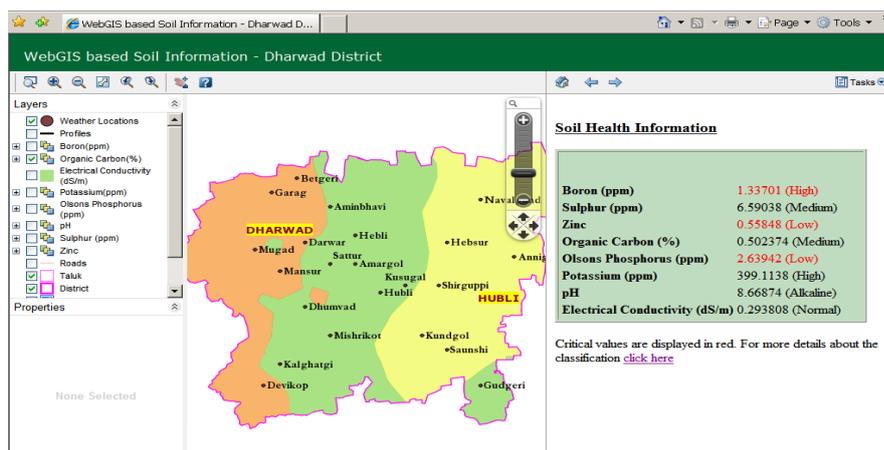
Figure 3. WebGIS-based Soil and Weather information system for Karnataka.

Learning materials and curriculum development on the Web: Agrocuri

During 2008, the parameters for the Agrocuri platform were finalized with user testing. During 2009, the platform was completely re-developed on Drupal, an Open Source content management system (which integrates well with open learning management system, the Moodle). It is available at www.agrocuri.org . It has Wiki's forum and blogs built-in specially designed workflows available for content authoring, review, approval and publication. Groups and sub-groups of contributors can work together on Agrocuri, which has unique feature that links content to an internationally-approved curriculum. AGROVOC is used on this platform to tag/index contributions (See Figure 4 below).
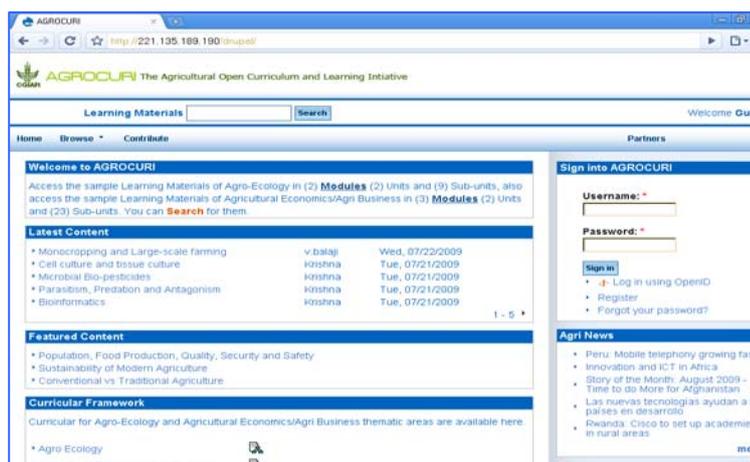
Figure 4. Screenshot of the redesigned AGROCURI portal.

We organized two workshops on Agrocuri and Open learning in agriculture at Patancheru (with IFPRI, University of Florida, University of Nairobi and India-based partners, May 2009) and at Nairobi (with IFPRI, RUFORUM, U Nairobi and 13 universities from SSA). The portal was tested extensively in Nairobi for user-friendliness and integrity of functions.

Auxiliary Activities contributing to the log-frame

The Institute adopted an Open Access policy, requiring all publications especially those in peer-reviewed journals to be made available to the public via a web-based repository. D-Space, used across many countries and institutions as the software application for Institutional repository, has been adopted as the platform. Besides pre-prints of journals publications, books and conference proceedings are also made available. As of Dec 2009, 794 full-text papers and 432 books (equivalent to about 40000 pages) are available on this repository, (http://openaccess.icrisat.org). All the entries here are "harvested" in the OAIster, which is the system for indexing open access publications across the globe.

A consultation on promoting OA, organized jointly with the FAO and ICAR (Sept 09) led to the launching of the OA repository of the Indian Agricultural Research Institute (IARI) (http://eprints.iari.res.in/). The IIT-Kanpur has built, with ICRISAT inputs, a software, AgroTags, to automatically tag research publications for depositing them in an OA repository. This technique uses a key extract of semantically linked terms from Agrovoc, developed by ICRISAT.

Inference from the use of video-conferencing as an outreach technique

We continued the trials on the use of satellite-based 2-way video-conferencing as a technique to exchange information on solution. Duration 2009, we conducted 66 sessions of 2 hours each. Drought mitigation was the most important topic for the users. Information sought was

more on changing the crops after the rainfall has failed. The exchanges were reported in the online forums(www.aaqua.org). Based on VC exchanges, text messages were generated on a trial basis to issue drought-related alerts, Over this period, we came to understand the following

- video-conferencing in real time with clients is management-intensive, and should be blended with partly pre-recorded discussions; this will reduce the stress on the presenter
- follow up with messaging on the mobile considerably reinforces the message

Impact pathways

All activities were designed to operate in a partnership mode:

- Joint design and operations led by an IARC with NARES and non-NARES partners have resulted in reasonable volume in generation of outreach materials (approximately 4500 pages equivalent in one year from NARES partners and others).

-At least one agricultural university has taken in a significant way to linking web-based technical information with delivery via mobile telephony. This university has generated about 2500 voice clips (less than 50 sec) as tips that can be used in conjunction with mobile telephony.

- a basic, functional, multi-partner model for linking information aggregation-storage-delivery/exchange in multiple modes is now available.

- crop knowledge models, in multiple human languages, can be used to build advanced digital content organizations in support of extension while inducing NARES engagement.

- revised Agrovoc can and is at the core of some content organization efforts in agriculture, such as Agropedia and Agro Tags, and Agrocuri. These involve CGIAR as well as NARES partners.

Output target 2009 10.1.1 Platform installed in 3 partner organizations:

Achievement of Output Target:
100%

Participating Countries:
India: Three States with population more than 25 millions: Karnataka, Uttar Pradesh, Andhra Pradesh; one with less than 25 million population: Uttarakhand; languages covered: three besides English

Participating Partners:
Indian Institute of Technology-Kanpur, University of Agricultural Sciences- Raichur, GB Pant University for Agriculture and Tech, National Academy for Agricultural Research Management,

Progress/Results:
Agropedia + aAQUA deployed in three agricultural universities in India (GB Pant Ag University, University of Ag Sci- Raichur; University of Ag Sci- Dharwad); extensive content creation on both these platforms from all these partners can be directly be seen at http://agropedia.net and at www.aaqua.org). The contributions in Agropedia from these partners are about 800% larger than ICRISAT's own contributions.

Special Project Funding:
Indian Council of Agricultural Research
<div align="right">V Balaji</div>

Output 10.2: New approaches for enhanced access to ICRISAT IPG's developed, tested and shared with partners

Output target 2009 10.2.1 New approach based on web services tested for localization with two partners:

Achievement of Output Target:
100%

Participating Countries:
India (both web and mobile telephony); Kenya (web)

Participating Partners:
IFPRI, RUFORUM, Indian Institute of Technology-Bombay, University of Agricultural Sciences-Raichur, GB Pant University for Agriculture and Technology

Progress/Results:
With the forum aAQUA, the GB Pant University and the UAS-Dharwad and UAS-Raichur have tested creating 687 unique messages to 17000 farmers via mobile phones using a web interface; they have also tested generating and sending 641 audio tips to just over 26000 farmers using a blend of web, mobile phone and call back by voice.

Special Project Funding:
Global- none; National- Indian Council of Agricultural Research.
<div align="right">V Balaji</div>

Publications

SNo.	ISSN No.	Journal Name	Journal Article
1.	0906-4710	Acta Agriculturae Scandinavica	**Ayoubi Sh, Khormali F** and Sahrawat KL. 2009. Relationships of barley biomass and grain yields to soil properties within a field in the arid region: use of factor analysis. Acta Agriculturae Scandinavica, Section B 59:107-117.
2.	0238-0161	Acta Agronomica Hungarica	SHARMA S and Chaudhary HK. 2009. Combining ability and gene action studies for yield-contributing traits in crosses involving winter and spring wheat genotypes. Acta Agronomica Hungarica 57:417-423.
3.	1684-5315	African Journal of Biotechnology	Gwata ET and Siambi M. 2009. Genetic enhancement of pigeonpea for high latitude areas in southern Africa. African Journal of Biotechnology 8(18):4413-4417. http://www.academicjournals.org/AJB
4.	1684-5315	African Journal of Biotechnology	MAMTA SHARMA, Rajeev Kumar Varshney, Joginedi Narayan Rao, SEETHA KANNAN, David Hoisington and Suresh Pande. 2009. Genetic diversity in Indian isolates of *Fusarium oxysporum* f. sp. *ciceris*, chickpea wilt pathogen. African Journal of Biotechnology 8(6):1016-1023 http://www.academicjournals.org/AJB
5.	0308-521X	Agricultural Systems	Hansen JW, Mishra A, Rao KPC, Indeje M and **Ngugi RK**. 2009. Potential value of GCM-based seasonal rainfall forecasts for maize management in semi-arid Kenya. Agricultural Systems 101:80–90.
6.	0308-521X	Agricultural Systems	Mazvimavi K and Twomlow S. 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agricultural Systems 101:20–29.
7.	0378-3774	Agricultural Water Management	**Garg Kaushal K,** Das BS, Safeeq M and Bhadoria PBS. 2009. Measurement and modeling of soil water regime in a lowland paddy field showing preferential transport. Agricultural Water Management 96(12):1705-1714.
8.	0167-8809	Agriculture, Ecosystems and Environment	MUTHURI CW, Ong CK, Craigon J, MATI B.M, NGUMI VW and Black CR. 2009. Chlorophyll content, gas exchange and water use efficiency of trees and maize in agroforestry systems in semi-arid Kenya. Agriculture, Ecosystems and Environment 129:497–507.
9.	0167-4366	Agroforestry Systems	Raju NL and Prasad MNV. 2009. Influence of growth hormones on adventitious root formation in semi-hardwood cuttings of *Celasturs paniculatus* Willd. - A contribution for rapid multiplication and conservation management. Agroforestry Systems 1-4.(http://www.springerlink.com/content/b2136vn6511k41r0).
10.	0972-2963	Animal Nutrition Feed Technology	*Blümmel M*, **Rao SS**, **Palaniswami S, Shah L** and Reddy BVS. 2009. Evaluation of sweet sorghum [*Sorghum bicolor* (L.) Moench] used for bio-ethanol production in the context of whole plant utilization. Animal Nutrition Feed Technology 9:1-10.
11.	0306-2619	Applied Energy	Divakara BN, Upadhyaya HD, Wani SP and Gowda CLL. 2009. Biology and genetic improvement of *Jatropha* curcas L.: A review. Applied Energy 732-742.
12.	0365-0340	Archives of Agronomy and Soil Science	Sahrawat KL 2009. The role of tolerant genotypes and plant nutrients in reducing acid-soil infertility in upland rice ecosystem: an appraisal. Archives of Agronomy and Soil Science 55:597-607.

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SNo.	ISSN No.	Journal Name	Journal Article
13.	0323-5408	Archives of Phytopathology and Plant Protection	Sharma R, Rao VP, Varshney RK, Prasanth VP, KANNAN S and Thakur RP. 2009. Characterization of pathogenic and molecular diversity in *Sclerospora graminicola*, the causal agent of pearl millet downy mildew. Archives of Phytopathology and Plant Protection DOI: 10.1080/03235400801939896
14.	0323-5408	Archives of Phytopathology and Plant Protection	Sharma R. 2009. Genetic differentiation of host limited forms of Colletotrichum truncatum from northwestern Himalayas. Archives of Phytopathology and Plant Protection 42:960-966.
15.	1872-8855	Arthropod Plant Interactions	Sharma HC, SUJANA G and **Manohar Rao D**. 2009. Morphological and chemical components of resistance to pod borer, *Helicoverpa armigera* in wild relatives of pigeonpea. Arthropod Plant Interactions 3:151-161.
16.	1835-2693	Australian Journal of Crop Science	Osiru MO, **Adipala E**, Olanya OM, KAPINGA R and **Lemaga B**. 2009. Yield stability analysis of sweet potato (*Ipomoea batatus* L.) cultivars in diverse environments. Australian Journal of Crop Science 3(4):213-220.
17.	1386-6141	Biocontrol	Dhillon MK and Sharma HC. 2009. Temperature influences the performance and effectiveness of field and laboratory strains of the ichneumonid parasitoid, *Campoletis chlorideae*. Biocontrol 54:743-750.
18.	0958-3157	Biocontrol Science and Technology	Dhillon MK and Sharma HC. 2009. Effects of *Bacillus thuringiensis* δ-endotoxins Cry1Ab and Cry1Acon the coccinellid beetle, *Cheilomenes sexmaculatus* (Coleoptera, Coccinellidae) under direct and indirect exposure conditions. Biocontrol Science and Technology 19(4):407-420.
19.	0006-3134	Biologia Plantarum	KHOLOVA J, **Sairam RK, Meena RC** and **Srivastava GC.** 2009. Response of maize genotypes to salinity stress in relation to osmolytes and metal-ions contents, oxidative stress and antioxidant enzymes activity nutrient. Biologia Plantarum 53(2): 249-256.
20.	1370-6233 eISSN 1780-4507	Biotechnology, Agronomy, Society and Environment	L'taief B, **Sifi B**, Zaman-Allah M, Hajji M and Lachaâl M. 2009. Effect of nitrogen fertilization, inoculation with Rhizobium sp. and precipitation on the biomass production and nitrogen content of chickpea. Biotechnology Agronomy Society and Environment 13(4):537-544. http://www.bib.fsagx.ac.be/base/eng/home/acknowledgment.html
21.	1370-6233 eISSN 1780-4507	Biotechnology, Agronomy, Society and Environment	Zaman-Allah M, **Sifi B**, L'Taief B, and El Aouni MH. 2009. Agronomical traits associated with salinity-tolerance in common bean (*Phaseolus vulgaris* L.). Biotechnology, Agronomy, Society and Environment 13(1):113-119. http://www.bib.fsagx.ac.be/base/eng/home/acknowledgment.html
22.	1370-6233 eISSN 1780-4507	Biotechnology, Agronomy, Society and Environment	Zaman-Allah M, **Sifi B,** L'Taief B, and El Aouni MH. 2009. Agronomical traits associated with salinity-tolerance in common bean (*Phaseolus vulgaris* L.). Biotechnology, Agronomy, Society and Environment 13(1):113-119.4:400–407. http://www.bib.fsagx.ac.be/base/eng/home/acknowledgment.html
23.	1471-2164	BMC Genomics	Close TJ, Bhat PR, Lonardi S, Wu Y, Rostoks N, Ramsay L, Druka A, Stein N, Svensson JT, Wanamaker S, Bozdag S, Roose ML, Moscou MJ, Chao S, Varshney RK, SzucsSato K, Hayes PM, Matthews DE, Kleinhofs A, Muehlbauer GJ, Young JD, Marshall DF, MADISHETTY KM, Fenton RD, Condamine P, Graner A, and Waugh R. 2009. Development and implementation of high-throughput SNP genotyping in barley. BMC Genomics 10:582 (Highly accessed article)
24.	1471-2164	BMC Genomics	Varshney RK, HIREMATH PJ, LEKHA PT, Kashiwagi J, BALAJI J, **Deokar AA**, Vadez V, Xiao Y, **Srinivasan R**, Gaur PM, **Siddique KHM,** Town CD and Hoisington DA. 2009. A comprehensive resource of drought- and salinity- responsive ESTs for gene discovery and marker development in chickpea *(Cicer arietinum* L.). BMC Genomics 10:523.

25.	1471-2229	BMC Plant Biology	**LEAL-BERTIOLI SCM**, **Jose ACVF**, **Alves-Freitas DMT**, **Moretzsohn MC**, **GUIMARAES PM**, **Nielen S**, **Vidigal BS**, **Pereira RW**, **Pike J**, **Favero AP**, **Parniske M**, Varshney RK and **Bertioli DJ**. 2009. Identification of candidate genome regions controlling disease resistance in Arachis. BMC Plant Biology 9: 112 .
26.	1344-7610	Breeding Science	<u>Subbarao GV</u>, <u>Kishii M</u>, <u>Nakahara K</u>, <u>Ishikawa T</u>, <u>Ban T</u>, <u>Tsujimoto H</u>, <u>George TS</u>, <u>Berry WL</u>, Hash CT, and <u>Ito O</u>. 2009. Biological nitrification inhibition (BNI)—Is there potential for genetic interventions in the Triticeae? Breeding Science 59:529-545.
27.	0936-577X	Climate Research	<u>Challinor AJ</u>, <u>Wheeler T</u>, <u>Hemming D</u> and Upadhyaya HD. 2009. Ensemble crop yield simulations: crop and climate uncertainties, sensitivities to temperature and genotype adaptation to climate change. Climate Research 38:117-127.
28.	0010-3624 eISSN: 1532-2416>	Communications in Soil Science and Plant Analysis	Srinivasa Rao C, **Vittal KPR**, **Venkateswarlu B**, Wani SP, Sahrawat KL, Marimuthu S and Kundu S. 2009. Carbon stocks in different soil types under diverse rainfed production systems in tropical India. Communications in Soil Science and Plant Analysis, 40:15.2338-2356.
29.	0256-0933	Crop Improvement	Gupta S K, Velu G, Rai KN and SUMALINI K.2009. Association of grain iron and zinc content with grain yield and other traits in pearl millet (*Pennisetum glaucum* (L.)R.Br.). Crop Improvement 36(2):4-7.
30.	0011-183X	Crop Science	Jorge Franco, José Crossa and Santosh Deshpande. **2009**. Hierarchical multiple-factor analysis for classifying genotypes based on phenotypic and genetic data. Crop Science 50:105-117.
31.	0011-183X	Crop Science	Upadhyaya HD, Gowda CLL, Reddy KN and Sube Singh. 2009. Augmenting the pearl millet [*Pennisetum glaucum* (L.) R. Br.)] core collection for enhancing germplasm utilization in crop improvement. Crop Science 49: 573-580.
32.	0011-183X	Crop Science	Upadhyaya HD, Pundir RPS, Dwivedi SL, Gowda CLL, Gopal Reddy V and Sube Singh. 2009. Developing a mini core collection of sorghum [Sorghum bicolor (L.) Moench] for diversified utilization of germplasm. Crop Science 49:1769-1780.
33.	1369-5266	Current Opinion in Plant Biology	Varshney RK, <u>Close TJ</u>, **Singh NK**, Hoisington DA and <u>Cook DR.</u> 2009. Orphan legume crops enter the genomics era! Current Opinion in Plant Biology 12:202–210.
34.	0011-3891	Current Science	Sahrawat KL, Rego TJ, **Murthy KVS** and Wani SP. 2009. Toxicity due to salinity caused by the addition of excess compost in potted plants. Current Science 97:1718-1719.
35.	1387-585X	Environment, Development and Sustainability	Shiferaw B, **Okello J** and **Reddy VR.** 2009. Adoption and adaptation of natural resource management innovations in smallholder agriculture: Reflections on key lessons and best practices. Environment, Development and Sustainability 11:601-619.
36.	0014-2336	Euphytica	*Bernier J, Kumar A,* Venuprasad R, <u>Spaner D</u>, **Verlukar S, Mandal NP, Sinha PK, Peeraju P, Dongre PR, Mahto RN**and*Atlin GN.* 2009. Characterization of the effect of rice drought resistance *qtl12.1* over a range of environments in the Philippines and eastern India. Euphytica 166:207-217.
37.	0014-2336	Euphytica	BHARDWAJ R, **Sandhu JS,** KAUR LIVINDER, Gupta SK, PM Gaur and Varshney R. 2009. Genetics of ascochyta blight resistance in chickpea. Euphytica. DOI 10.1007/s10681-009-0020-7.

38.	0014-2336	Euphytica	**Kassahun B**, Bidinger FR, Hash CT and **Kuruvinashetti MS**. 2009. Stay-green expression in early generation sorghum [*Sorghum bicolor* (L.) Moench] QTL introgression lines. Euphytica. DOI:10.1007/s10681-009-0108-0.
39.	0014-2336	Euphytica	**KOTAPALLY P**, Gaur PM, **Katiyar SK**, Crouch JC, BUHARIWALA HK, Pande S and Gali KK. 2009. Mapping and validation of QTLs for resistance to an Indian isolate of Ascochyta blight pathogen in chickpea. Euphytica 165:79-88.
40.	0014-2336	Euphytica	Saxena KB and Kumar RV. 2009. Insect-aided natural out-crossing in four wild relatives of pigeonpea. Euphytica [Online First] 7pp. http://dx.doi.org/10.1007/s10681-009-0088-0
41.	0014-2336	Euphytica	Upadhyaya HD, Reddy LJ, Gowda CLL and Sube Singh. 2009. Phenotypic diversity in cold-tolerant peanut (*Arachis hypogaea* L.) germplasm. Euphytica 165: 279-291.
42.	0014-2336	Euphytica	Venuprasad R, *BOOL ME, DALID CO, Bernier J, Kumar A* and *Atlin GN*.2009. Genetic loci responding to two cycles of divergent selection for grain yield under drought stress in a rice breeding population. Euphytica 167:261-269.
43.	1161-0301	European Journal of Agronomy	Whitbread A, Robertson M, Carberry, P and Dimes J. 2010. Applying farming systems simulation to the development of more sustainable smallholder farming systems in Southern Africa. European Journal of Agronomy 32:51-58. 0.1016/j.eja.2009.05.004
44.	0014-4797	Experimental Agriculture	*Trouche G*, VOM BROCKE K, **Aguirre S** and *Chow Z. 2009*. Giving new sorghum variety options to resource-poor farmers in Nicaragua through participatory variety selection. Experimental Agriculture 45:451-467.
45.	0378-4290	Field Crops Research	Bernier J, Serraj R, Kumar A, Venuprasad R, IMPA S, **Veeresh Gowda RP,** OANE R, Spaner D, and Atlin G. 2009. The large-effect drought-resistance QTL *qtl12.1* increases water uptake in upland rice. Field Crops Research 110:139-146.
46.	0378-4290	Field Crops Research	Devi JM, Sinclair TR, Vadez V and Krishnamurthy L 2009. Peanut genotypic variation in transpiration efficiency and decrease transpiration during progressive soil drying. Field Crops Research 114:280-285.
47.	0378-4290	Field Crops Research	*Kumar A*, **Verulkar S**, *Dixit S, Chauhan B, Bernier J,* Venuprasad R, *Zhao D* and **Shrivastava MN**. 2009. Yield and yield-attributing traits of rice (*Oryza sativa* L.) under lowland drought and suitability of early vigor as a selection criterion. Field Crops Research 114:99-107.
48.	0378-4290	Field Crops Research	NCUBE B, Dimes J, van Wijk M, Twomlow S and Giller K. 2009. Productivity and residual benefits of grain legumes to sorghum under semi-arid conditions in south-western Zimbabwe: Unravelling the effects of water and nitrogen using a simulation model. Field Crops Research 110:173-184.
49.	0378-4290	Field Crops Research	Uchino H, **Iwama K**, **Jitsuyama Y**, **YUDATE T** and **Nakamura S**. 2009. Yield losses of soybean and maize by competition with interseeded cover crops and weeds in organic-based cropping systems. Field Crops Research 13:342-351.
50.	0925-9864	Genetic Resources and Crop Evolution	Evans Mutegi, Fabrice Sagnard, Moses Muraya , **Ben Kanyenji**, **Bernard Rono**, *Caroline Mwongera*, **Charles Marangu**, **Joseph Kamau**, Heiko Parzies, SANTIE DE VILLIERS, Kassa Semagn, Pierre Sibiry Traoré and MARYKE LABUSCHAGNE. 2009. Ecogeographical distribution of wild, weedy and cultivated *Sorghum bicolor* in Kenya: Implications for conservation and crop-to-wild gene flow. Genetic Resources and Crop Evolution. DOI 10.1007/s10722-009-9466-7.

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51.	0925-9864	Genetic Resources and Crop Evolution	**Mutegi E.**, Sagnard F, Muraya M, **Kanyenji B**, **Rono B**, **MWONGERA C**, **MARANGU C**, **Kamau J**, Parzies H, DE VILLIERS S, Semagn K, Traoré PS and LABUSCHAGNE M. 2009. Ecogeographical distribution of wild, weedy and cultivated *Sorghum bicolor* (L.) Moench in Kenya: Implications for conservation and crop-to-wild gene flow. Genetic Resources and Crop Evolution. Doi 10.1007/s10722-009-9466-7
52.	0925-9864	Genetic Resources and Crop Evolution	**Salem KFM**, Varshney RK, RÖDER MS and Börner A. 2009. EST-SSR based estimates on functional genetic variation in a barley (*Hordeum vulgare* L.) collection from Egypt. Genetic Resources and Crop Evolution doi:10.1007/s10722-009-9489-0.
53.	0019-5022	Indian Journal of Agricultural Sciences	BHARDWAJ R**, Sandhu JS and** SK Gupta. 2009. Gene action studies and combining ability estimates for yield and other quantitative traits in chickpea (*Cicer arietinum*). Indian Journal of Agricultural Sciences 79(11): 897-900.
54.	0019-5022	Indian Journal of Agricultural Sciences	**Panwar S, Kumar A,** Rathore A**,** and **Jaggi N**. 2009. Fitting nonlinear Gompertz model to banana production growth data. Indian Journal of Agricultural Sciences 79(2):106-109.
55.	0253-4355	Indian Journal of Plant Protection	Kumar PL, Prasadarao RDVJ, Reddy AS, MADHAVI JK, ANITHA K and Waliyar F. 2009. The emergence, spread and strategies for controlling *Tobacco streak virus* menace in India Indian Journal of Plant Protection 36:1-8.
56.	1567-1348	Infection, Genetics and Evolution	**Olivier Gascuel, ALIA BENKAHLA, Winston Hide, Dan Masiga and Trushar Shah. 2009.** Bioinformatics of African pathogens and vectors. Infection, Genetics and Evolution 9(3):305-307.
57.	0973-8363	International Journal of Integrative Biology	GAUTAMI B, Ravi K, **LAKSHMI NARASU M**, Hoisington DA and Varshney RK. 2009. Novel set of groundnut SSRs for genetic diversity and interspecific transferability. International Journal of Integrative Biology (IJIB) 7:100-106.
58.	0168-1605	International Journal of Food Microbiology	**MUTEGI CK**, Ngugi HK, HENDRICKS SL and Jones RB. 2009. Prevalence and factors associated with aflatoxin contamination of peanuts from western Kenya. International Journal of Food Microbiology 130:27-34.
59.	1742-7584	International Journal of Tropical Insect Science	Ranga Rao GV, Rameshwar Rao V**, Prasanth VP, Khannal NP, Yadav NK** and Gowda CLL. 2009. Farmers' perception on plant protection in India and Nepal: a case study. International Journal of Tropical Insect Science 29 (3):158-168.
60.	0022-0957	Journal of Experimental Botany	**Guo P**, Baum M, *GRANDO S*, Ceccarelli S, Bai G, Li R, KORFF M, Varshney RK, Graner A and *Valkoun J*. 2009. **Differentially expressed genes** between drought-tolerant and drought-sensitive barley genotypes in response to drought stress during the reproductive stage. Journal of Experimental Botany 60:3531-3544.
61.	0021-857X	Journal of Agricultural Economics	Asfaw S, *MITHOEFER D* and Waibel H. 2009. Food-safety standards, pesticide use and farm level productivity: The case of high-value crops in Kenya. Journal of Agricultural Economics 60(3):645-667.
62.	0931-2250	Journal of Agronomy and Crop Science	**Banterng Poramate**, Hoogenboom Gerrit, **Patanothai Aran**, Singh Piara, Wani Suhas, Pathak P, **Tongpoonpol S, Atichart S, SRIHABAN P, Buranaviriyakul S, Jintrawet, Attachai TC** and **NGUYEN T**. 2009. Application of the cropping system model (CSM)-CROPGRO-soybean for determining optimum management strategies for soybean in tropical environments. Journal of Agronomy and Crop Science (http://www3.interscience.wiley.com/cgi-bin/fulltext/122647650/PDF START).

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

63.	0931-2250	Journal of Agronomy and Crop Science	**Bhatia VS**, Singh P, Kesava Rao AVR, Srinivas K and Wani SP. 2009. Analysis of water non-limiting and water limiting yields and yield gaps of groundnut in India using CROPGRO-peanut model. Journal of Agronomy and Crop Science 195:455-463.
64.	0931-2250	Journal of Agronomy and Crop Science	KAUR S**, Gupta AK,** KAUR N, **Sandhu JS** and Gupta SK.2009. **Antioxidative** enzymes and sucrose synthase contribute to cold stress tolerance in chickpea. Journal of Agronomy and Crop Science 195(5):393-397.
65.	0931-2048	Journal of Applied Entomology	<u>Clement SL</u>, Sharma HC, <u>Muehlbauer FJ, Elberson LR, Mattinson DS</u> and <u>Fellman JK</u>. 2009. Resistant to beet armyworm in recombinant inbred line population. Journal of Applied Entomology. Doi: 10.1111/j.1439-0418.2009.01411.x.
66.	1364-5072	Journal of Applied Microbiology	**GULATI P**, Varshney RK and **Virdi JS**. 2009. Multilocus variable number tandem repeat analysis as a tool to discern genetic relationships among strains of *Yersinia enterocolitica* biovar 1A. Journal of Applied Microbiology 107: 875–884.
67.	1226-8615	Journal of Asia-Pacific Entomology	Reddy PN, Alikhan P, DEVI KU, Sharma HC and <u>Reinke A</u>. 2009. Treatment of millet crop (*Sorghum bicolor*) with the entomopathogenic fungus (*Beauveria bassiana*)to combat the infestation by the stem borer, *Chilo partellus* Swinhoe(Lepidoptera: Pyralidae). Journal of Asia-Pacific Entomology 12:221-226.
68.	0022-0957	Journal of Experimental Botany	KHOLOVA J, Hash CT, KAKKERA A, KOCOVA M and Vadez V. 2009. Constitutive water-conserving mechanisms are correlated with the terminal drought tolerance of pearl millet [*Pennisetum glaucum* (L.) R. Br.] Journal of Experimental Botany (doi:10.1093/jxb/erp314)
69.	0022-0957	Journal of Experimental Botany	STEPHANIE A FISCHINGER, MARIETA HRISTOZKOVA, Zaman-Allah Mainassara and Joachim Schulze. 2009. Elevated CO2 concentration around alfalfa nodules increases N2 fixation. Journal of Experimental Botany 287:1-10.
70.	ISSN:1459-0255 eISSN:1459-0263	Journal of Food, Agriculture & Environment	Gwata ET and Silim SN. 2009. Utilization of landraces for the genetic enhancement of pigeonpea in Eastern and Southern Africa. Journal of Food, Agriculture & Environment 7:803-806 .
71.	0931-1785	Journal of Phytopathology	Osiru MO, Olanya OM, **Adipala E**, **Lemaga B** and *KAPINGA R*. 2009. Stability of sweet potato cultivars to Alternaria leaf and stem blight disease. Journal of Phytopathology 157:172-180.
72.	0931-1785	Journal of Phytopathology	**Sudhisha J**, **Kumar SA**, Thakur RP, Rao VP and **Shetty HS**. 2009. Molecular characterization of *Sclerospora graminicola*, the incitant of pearl millet downy mildew using ISSR markers. Journal of Phytopathology 157:748-755.
73.	0971-7811	Journal of Plant Biochemistry and Biotechnology	Varshney RK and **DUBEY A**. 2009. Novel genomic tools and modern genetic and breeding approaches for crop improvement. Journal of Plant Biochemistry and Biotechnology 18:127-138.
74.	1436-8730	Journal of Plant Nutrition and Soil Science	Sahrawat KL, **Murthy KVS** and Wani SP 2009. Comparative evaluation of Ca chloride and Ca phosphate for extractable sulfur in soils with a wide range in pH. Journal of Plant Nutrition and Soil Science 172:404-407.
75.	1125-4653	Journal of Plant Pathology	Thakur RP, Rao VP and Sharma R. 2009. Temporal virulence change and identification of resistance in pearl millet germplasm to diverse pathotypes of *Sclerospora graminicola.* Journal of Plant Pathology 91: 691-698.
76.	0176-1617	Journal of Plant Physiology	BHATNAGAR-MATHUR P, <u>JYOTSANA DEVI M,</u> Vincent V and Sharma KK 2009. Differential biochemical responses of transgenic groundnut under water deficit conditions. Journal of Plant Physiology 166:1207-1217.

Bold=**NARES**; Underline=<u>ARI</u>; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

77.	****-****	Karnataka Journal of Agricultural Sciences	Dhillon MK and Sharma HC. 2009. Impact of *Bt*-engineered cotton on target and nontarget arthropods, toxin flow through different trophic levels, and seedcotton yield. Karnataka Journal of Agricultural Sciences (Special Issue) 22:462-466.
78.	1380-3743	Molecular Breeding	BHATNAGAR-MATHUR P, Vincent V, JYOTSANA DEVI M, LAVANYA M, **VANI G** and Sharma KK. 2009. Over expression of Vigna P5CSF129A gene in chickpea for enhancing drought tolerance. Molecular Breeding 23:591–606.
79.	1380-3743 eISSN:1572-9788	Molecular Breeding	*Jianbing Yan,* **XIAOHONG YANG**, TrusharShah, *Héctor Sánchez-Villeda, Jiansheng Li,* MARILYN WARBURTON, **Yi Zhou**, *Jonathan H Crouch* and Yunbi Xu. 2009. High-throughput SNP genotyping with the golden gate assay in maize. Molecular Breeding. DOI:10.1007/s11032-009-9343-2 Published online 22nd October 2009.
80.	1380-3743	Molecular Breeding	*Singh PK*, Mergoum M, Adhikari TB, Shah T, Ghavami F and Kianian SF. 2009. Genetic and molecular analysis of wheat tan spot resistance effective against Pyrenophora tritici-repentis races 2 and 5. Molecular Breeding DOI 10.1007/s11032-009-9336-1 Published online 27th September 2009.
81.	1380-3743	Molecular Breeding	Varshney RK, Baum M, **Guo P**, *GRANDO S, Ceccarelli S* and Graner A. 2009. Features of SNP and SSR diversity in a set of ICARDA barley germplasm collection. Molecular Breeding Doi 10.1007/s11032-009-9373-9.
82.	1380-3743	Molecular Breeding	Varshney RK, Penmetsa RV, **Dutta S**, **Kulwal PL**, *Saxena RK*, **DATTA S**, **Sharma TR**, Rosen B, CARRASQUILLA-GARCIA N, Farmer AD, **DUBEY A**, Saxena KB, Gao J, **Fakrudin B, Singh MN**, **Singh BP**, **Wanjari KB**, YUAN M, Srivastava RK, Kilian A, Upadhyaya HD, MALLIKARJUNA N, Town CD, Bruening GE, He G, May GD, McCombie R, Jackson SA, **Singh NK** and Cook DR. 2009. Pigeonpea genomics initiative (PGI): an international effort to improve crop productivity of pigeonpea *(Cajanus cajan* L.). Molecular Breeding doi:10.1007/s11032-009-9327-2.
83.	1617-416X	Mycological Progress	Varshney RK, Pande S, KANNAN S, Mahender T, SHARMA M, Gaur P and Hoisington DA. 2009. Assessment and comparison of AFLP and SSR based molecular genetic diversity in Indian isolates of *Ascochyta rabiei*, a causal agent of ascochyta blight in chickpea *(Cicer aeritinum* L.). Mycological Progress 8:87-97.
84.	0028-0836	Nature	Paterson AH, Bowers JE, Bruggmann R, Dubchak I, Grimwood J, Gundlach H, Haberer G, Hellsten U, Mitros T, Poliakov A, Schmutz J, Spannagl M, Tang H, Wang X, Wicker T, Bharti AK, Chapman J, Feltus FA, Gowik U, Grigoriev IV, Lyons E, Maher CA, Martis M, Narechania A, Otillar RP, Penning BW, Salamov AA, Wang Y, Zhang L, Carpita NC, Freeling M, Gingle AR, Hash CT, Keller B, Klein P, Kresovich S, McCann MC, Ming R, Peterson DG, Rahman MU, Ware D, Westhoff P, Mayer KFX, Messing J and Rokhsar DS. 2009. The *Sorghum bicolor* genome and the diversification of grasses. Nature 457:551-556. DOI:10.1038/nature07723
85.	1385-1314 eISSN: 1573-0867	Nutrient Cycling in Agroecosystem Journal	Fatondji D, Martius C, **Zougmore R**, Vlek PLG; Bielders CL and Koala S. 2009. Decomposition of organic amendment and nutrient release under the zai technique in the Sahel. Nutrient Cycling in Agroecosystem Journal 85:225-239. DOI 10.1007/s10705-009-9261-z
86.	0095-3679	Peanut Science	Farid Waliyar, Reddy SV and Lava Kumar P. 2009. Review of immunological methods for the quantification of aflatoxins in peanut and others foods. Peanut Science 36:54-59.
87.	0095-3679	Peanut Science	Nigam SN, Waliyar F, ARUNA R, Reddy SV, *Lava Kumar P*, Craufurd PQ, Diallo AT, Ntare BR and Upadhyaya HD. 2009. Breeding peanut for resistance to aflatoxin contamination at ICRISAT. Peanut Science 36:42-49.

88.	1435-8603	Plant Biology	Ratnakumar P, Vadez V, Nigam SN and Krishnamurthy L. 2009. Assessment of transpiration efficiency in peanut (*Arachis hypogaea* L.) under drought by lysimetric system. Plant Biology 11:124-130.
89.	0179-9541	Plant Breeding	Saxena KB, Sultana R, Mallikarjuna N, **Saxena RK**, Kumar RV, **Sawargaonkar SL** and Varshney RK. 2009. Male-sterility systems in pigeonpea and their role in enhancing yield. Plant Breeding 128: 1-10.
90.	0179-9541	Plant Breeding	Saxena RK, Prathima C, Saxena KB, Hoisington DA, Singh NK and Varshney RK. 2009. Novel SSR markers for polymorphism detection in pigeonpea (*Cajanus* spp.). Plant Breeding Doi: 10.1111/j.1439-0523.2009.01680.
91.	0179-9541	Plant Breeding	Saxena RK, Saxena KB, Kumar RV, Hoisington DA and Varshney RK. 2009. Simple sequence repeat-based diversity in elite pigeonpea genotypes for developing mapping populations to map resistance to *Fusarium* wilt and sterility mosaic disease. Plant Breeding Doi: 10.1111/j.1439-0523.2009.01698.
92.	0179-9541	Plant Breeding	Varshney RK, Mahendar T, ARUNA R, Nigam SN, NEELIMA K, Vadez V and Hoisington DA. 2009. High level of natural variation in a groundnut *(Arachis hypogaea* L.) germplasm collection assayed by selected informative SSR markers. Plant Breeding 128:86-94.
93.	0140-7791	Plant Cell and Environment	<u>Flowers TJ</u>, Gaur PM, Gowda CLL, Krishnamurthy L, <u>Samineni S</u>, <u>Siddique KHM</u>, <u>Turner NC</u>, Vadez V, Varshney RK and <u>Colmer TD</u>. 2009. Salt sensitivity in chickpea. Plant Cell and Environment. doi: 10.1111/j.1365-3040.2009.02051.x
94.	0140-7791	Plant Cell and Environment	<u>WITZEL K</u>, <u>WEIDNER A</u>, <u>Surabhi GK</u>, Varshney RK, <u>Kuenze G</u>, <u>Buck-Sorlin GH</u>, <u>Andreas Börner A</u> and <u>Mock HP</u>. 2009. Comparative analysis of the grain proteome fraction in barley genotypes with contrasting salinity tolerance during germination. Plant Cell and Environment. doi: 10.1111/j.1365-3040.2009.02071.x.
95.	1479-2621	Plant Genetic Resources: Characterization and Utilization	Upadhyaya HD, Reddy KN, Irshad Ahmed M, Gowda CLL and HAUSSMANN BIG. 2009. Identification of geographical gaps in the pearl millet germplasm conserved at ICRISAT genebank from West and Central Africa. Plant genetic Resources: characterization and Utilization. Published on line in open assess journal Plant Genetic Resources: Characterization and Utilization. Published on line 1–7; doi:10.1017/S147926210999013X
96.	0168-9452	Plant Science	LEELA T, Wani SP, SEETHA KANNAN, **Naresh Beerelli**, SREEDEVI TK, David A Hoisington, PRATHIBHA DEVI and Rajeev K. Varshney. 2009. AFLP-based molecular characterization of an elite germplasm collection of Jatropha curcas L., a biofuel plant. Journal of Plant Science 176:505-513.
97.	0168-9452	Plant Science	Nayak SN, JAYASHREE B, Upadhyaya HD, Hash CT, Kavi Kishor PB, Chattopadhyay D, Rodriquez LM, Blair MW, Michael Baum, McNally K, This D, Hoisington DA and Varshney RK. 2009. Isolation and sequence analysis of DREB2A homologues in three cereal and two legume species. Plant Science 177:460-467.
98.	0032-079X eISSN: 1573-5036	Plant and Soil	<u>Devi JM</u>, <u>Sinclair TR</u>, Vadez V 2009. Genotypic variability among peanut (*Arachis hypogea* L.) in sensitivity of nitrogen fixation to soil drying. Plant and Soil. DOI: 10.1007/s11104-009-0185-9.
99.	1932-6203	PLoS ONE	Kelkar A, Thakur V, Ramaswamy R, DEOBAGKAR D 2009. Characterisation of inactivation domains and evolutionary strata in human X chromosome through markov segmentation. PLoS ONE 4(11): e7885

Bold=**NARES**; Underline=<u>ARI</u>; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

100.	0038-0768	Soil Science and Plant Nutrition	Gopalakrishnan S, Watanabe T, <u>Ito O</u>, Zakir Hossain AKM, <u>Pearse SJ</u> and <u>Subbarao GV</u>. 2009. Biological nitrification inhibition by *Brachiaria humidicola* roots varies with soil type and inhibits nitrifying bacteria, but not other major soil microorganisms. Soil Science and Plant Nutrition55(5): 725-733.
101.	0038-0768	Soil Science and Plant Nutrition	Subramaniam Gopalakrishnan, Takashi Watanabe, Stuart J Pearse, Osamu Ito, Zakir AKM Hossain and Guntur V Subbarao. 2009. Biological nitrification inhibition by Brachiaria humidicola roots varies with soil type and inhibits nitrifying bacteria, but not other major soil microorganisms. Soil Science and Plant Nutrition 55: 725-733.
102.	0038-0768	Soil Science and Plant Nutrition	Takeshi Watanabe, **Luu Hong Man**, Duong Minh Vien, **Vu Tien Khang**, **NGUYEN NGOC HA**, Tran Ba Linh and **Osamu Ito**. 2009. Effects of continuous rice straw compost application on rice yield and soil properties in the Mekong Delta. Soil Science and Plant Nutrition 55:754-763.
103.	0038-0768	Soil Science and Plant Nutrition	Takeshi Watanabe, **Tran Thuc Son**, Ngo Ngoc Hung, **Nguyen Van Truong**, Tran Quang Giau**, Kentaro Hayashi** and **Osamu Ito**; Measurement of ammonia volatilization from flooded paddy fields in Vietnam. Soil Science and Plant Nutrition 55:793-799.
104.	0266-0032	Soil Use and Management	NCUBE B, Twomlow SJ, Dimes JP, <u>van Wijk MT</u> and <u>Giller KE.</u> 2009. Resource flows, crops and soil fertility management in smallholder farming systems in semi-arid Zimbabwe. Soil Use and Management 25:78–90.
105.	0266-0032	Soil Use and Management	Valluru R, Vadez V, Hash CT and Padmaja K 2009. A minute P application contributes to a better establishment of pearl millet (*Pennisetum americanum*) seedling in P-deficient soils. Soil Use and Management. Doi: 10.1111/j.1475-2743.2009.00245.x
106.	0040-5752	TAG Theoretical and Applied Genetics	**YANLI LU**, *Jianbing Yan*, **CLAUDIA T GUIMARÃES**, *Suketoshi Taba*, **ZHUANFANG HAO**, **Shibin Gao**, **Shaojiang Chen, Jiansheng Li, Shihuang Zhang**, *Bindiganavile S Vivek, Cosmos Magorokosho, Stephen Mugo, Dan Makumbi*, **Sidney N Parentoni**, *TrusharShah*, **Tingzhao Rong**, *Jonathan H Crouch* and*Yunbi Xu*. 2009. Molecular characterization of global maize breeding germplasm based on genome-wide single nucleotide polymorphisms. TAG Theoretical and Applied Genetics, 120(1):93-115. DOI10.1007/s00122-009-1162-7
107.	0040-5752	Theoretical and Applied Genetics	Ramu P, **Kassahun B,** Senthilvel S, Kumar CA, JAYASHREE B, Folkertsma RT, **Reddy LA, Kuruvinashetti MS**, HAUSSMANN BIG and Hash CT. 2009. Exploiting rice-sorghum synteny for targeted development of EST-SSRs to enrich the sorghum genetic linkage map. Theoretical and Applied Genetics 119:1193-1204. Doi 10.1007/s00122-009-1120-4.
108.	0040-5752	Theoretical and Applied Genetics	Varshney RK, **Bertioli DJ**, **Moretzsohn M**, Vadez V, Krishnamurthy L, ARUNA R, Nigam SN, Moss B, KANNAN S, Ravi K, <u>He G</u>, <u>Knapp SJ</u> and Hoisington DA. 2009. The first SSR-based genetic linkage map for cultivated groundnut (*Arachis hypogaea* L.). Theoretical and Applied Genetics 118:729-739.
109.	0040-5752	Theoretical and Applied Genetics	Venuprasad R, *DALID CO, DEL VALLE M, Zhao D, Espiritu M, STA CRUZ MT, Amante M, Kumar A* and *Atlin GN*. 2009. Identification and characterization of large-effect quantitative trait loci (QTL) for grain yield under lowland drought stress in rice using bulk-segregant analysis (BSA). Theoretical and Applied Genetics 120:177-190.
110.	0019-4816	The Indian Forester	Divakara BN. 2009. Variation and character association for various pulp biochemical traits in *Tamarindus indica* L. The Indian Forester 135:57-61.

111.	1036-9872	The Rangeland Journal volume	Amede T, Descheemmaeker K, Peden D and van Rooyen A. 2009. Harnessing benefits from improved water productivity in crop-livestock systems of sub-Saharan Africa: Synthesis. The Rangeland Journal volume 31(2):169-178.
112.	0167-7799	Trends in Biotechnology	Varshney RK, **NAYAK SN**, <u>May GD</u>, and <u>Jackson SA</u>. 2009. Next-generation sequencing technologies and their implications for crop genetics and breeding. Trends in Biotechnology 27:522-30.
113.	1682-3974	Asian Journal of Plant Sciences	Issoufou M, Zaman-Allah M, Ferchichi A and **Ferjani E**. 2008. Clipping effects on the growth variation. Water use efficiency and photosynthetic activity in buffel grass (*Cenchrus ciliaris* L.) Poaceae. Asian Journal of Plant Sciences 7(1):95-99. http://scialert.net/qredirect.php?doi=ajps.2008.95.99&linkid=pdf
114.	0022-1333	Indian Journal of Genetics	**SREELATHA E**, Gowda CLL, **Gour TB**, Sharma HC, Ramesh S and Upadhyaya HD**.** 2008. Genetic analysis of pod borer (*Helicoverpa armigera*) resistance and grain yield in *desi* and *kabuli* chickpeas (*Cicer arietinum*) under unprotected conditions. Indian Journal of Genetics 68:406-413.
115.	0253-4355	Indian Journal of Plant Protection	Dhillon MK and Sharma HC. 2008. Influence of temperature and *Helicoverpa armigera* food on survival and development of the parasitoid, *Campoletis chlorideae*. Indian Journal of Plant Protection 36(2):240-244.
116.	0253-4355	Indian Journal of Plant Protection	Gopala Swamy SVS, Sharma HC, Subbaratnam GV, Siva Kumar C and Sharma KK. 2008. Interaction of *Helicoverpa armigera* with putative transgenic plants of pigeonpea. Indian Journal of Plant Protection 36: 183-185.
117.	0253-4355	Indian Journal of Plant Protection	Gopalaswamy SVS, Sharma HC, **Subbaratnam GV** and Sharma KK. 2008. Field evaluation of transgenic pigeonpea plants for resistance to *Helicoverpa armigera*. Indian Journal of Plant Protection 36: 228-234.
118.	0253-4355	Indian Journal of Plant Protection	Kumar S Ch, Sharma HC, NARASU LM and Pampapathy G. 2008. Mechanisms and diversity of resistance to *Atherigona soccata* in *Sorghum bicolor*. Indian Journal of Plant Protection 36: 249-256.
119.	0253-4355	Indian Journal of Plant Protection	SIREESHA K, **Sridhar Kumar Ch**, Ranga Rao GV, **Arjuna Rao P** and <u>Lava Kumar P</u>. 2008. Laboratory disinfectants as preservatives for *Helicoverpa armigera* nucleopolyhedrovirus Indian Journal of Plant Protection 36(2): 257-259.
120.	0253-4355	Indian Journal of Plant Protection	Siva Kumar C, Sharma HC, **LAKSHMI NARASU M** and Pampapathy G. 2008. Mechanisms and diversity of resistance to shoot fly, *Atherigona soccata* in *Sorghum bicolor*. Indian Journal of Plant Protection36:249-256.
121.	1742-7584 eISSN: 1742-7592	International Journal of Tropical Insect Science	SUJANA G, Sharma HC and **Manohar Rao, D**. 2008. Antixenosis and antibiosis components of resistance to pod borer, *Helicoverpa armigera* in wild relatives of pigeonpea. International Journal of Tropical Insect Science 28: 191-200.
122.	0972-1665	Journal of Agrometeorology	Piara Singh**,** Srinivas K, Nageswara Rao V and **Giridhara Krishna T**. 2008. Cropping systems options in relation to ENSO phase for Nandyal in Andhra Pradesh —A simulation analysis. Journal of Agrometeorology (Special issue – Part I):150-158.
123.	0030-7270	Outlook on Agriculture	*MITHOEFER D*, Nang'ole E and Asfaw S. 2008. Smallholder Access to the export market: The case of vegetables in Kenya. Outlook on Agriculture 37(3):203-211.
124.	0179-9541	Plant Breeding	KAMALA V, Sharma HC, **Manohar Rao D**, Varaprasad KS and BRAMEL PJ. 2008. Wild relatives of sorghum as sources of resistance to sorghum shoot fly, *Atherigona soccata*. Plant Breeding 128: 137-142.

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SNo.	ISSN No.	Journal Name	Journal Article
1.	1021-9730	African Crop Science Journal	**Bucheyeki TL**, **Gwanama C**, MGONJA M, **Chisi M**, Folkertsma R and **Mutegi E**. 2009. Genetic variability characterization of Tanzania sorghum landraces based on Simple Sequence Repeats (SSR) molecular and morphological markers. African Crop Science Journal 17(2):71-86.
2.	1993-3738	African Journal of Agricultural and Resource Economics	Shiferaw B, **ObareG**, Muricho G and Silim S. 2009. Leveraging institutions for collective action to improve markets for smallholder producers in less-favored areas. African Journal of Agricultural and Resource Economics 3 (1):1-19.
3.	0971-3441 eISSN: 0974-0279	Agricultural Economics Research Review	**Adhiguru P**, Birthal PS and **B Ganesh Kumar**. 2009. Strengthening pluralistic agricultural information delivery system in India. Agricultural Economics Research Review 22: 71-79.
4.	0971-3441 eISSN: 0974-0279	Agricultural Economics Research Review	**Kumar P, Joshi PK** and Birthal PS. 2009. Demand projections for food grains in India. Agricultural Economics Research Review 22: 237-247.
5.	0971-3441 eISSN: 0974-0279	Agricultural Economics Research Review	**Palanisami K**, **Suresh Kumar D**, Wani SP and *Giordano Mark*. 2009. Evaluation of watershed development programmes in India - Using economic surplus method. Agricultural Economics Research Review 22:197-207.
6.		Agricultural Innovations for Sustainable Development	Osiru MO, Monyo ES, Waliyar F, **CHINYAMUNYAMU B**, **Mponda O** and Siambi M. 2009. Participatory development of improved groundnut varieties for East and Southern Africa. Agricultural Innovations for Sustainable Development 1(1):35-40.
7.	0305-0920 eISSN: 1751-6900	Appropriate Technology	Saxena KB. 2009. A hybrid pea for the drylands. Appropriate Technology 36:38-39.
8.	1749-0596	Bioremediation, Biodiversity and Bioavailability	PADMALATHA K, Jayaram K, Raju NL, Prasad MNV and Rajesh Arora. 2009. Ethnopharmacological and biotechnological significance of *Vitex*. Bioremediation, Biodiversity and Bioavailability 3(1):6-14.
9.	1756-0500	BMC Research Notes	JAYASHREE B, Bhanuprakash A, Jami A, Reddy PS, Nayak S and Varshney RK. 2009. Perl module and PISE wrappers for the integrated analysis of sequence data and SNP features. BMC Research Notes 24:2-92.
10.	1756-0500	BMC Research Notes	Odeny DA, JAYASHREE B, Gebhardt C and Crouch J. 2009. New microsatellite markers for pigeonpea *(cajanus cajan (L.) millsp.)*. BMC Research Notes 6:2-35.
11.	0578-039X	Chronica Horticulturae	Pasternak D, **Senbeto D**, Nikiema A, Kumar S, Dougbedji F, Woltering L, Ratnadass A and Ndjeunga J. 2009. Bioreclamation of degraded lands with women empowerment in Africa. Chronica Horticulturae 49:24-27.
12.		Crop Care	**Shetty HS, Niranjan-Raj S, Sudisha J**, Thakur RP, Rai, KN, **Khairwal**, IS, NEGI SANJANA and **Mahala** RS. 2009. *Pyricularia* blast of pearl millet in India. Crop Care 35 (1): 53-58.
13.	1547-3465	Ethnobotany Research & Applications	Ayantunde AA, Hiernaux P, Brieier M, Udo H and Tabo R. 2009. Uses of local plant species by agropastoralists in South-western Níger. Ethnobotany Research & Applications 7:53-66.
14.	1876-4517 eISSN: 1876-4525	Food Security	Nalini Mallikarjuna and David Hoisington. 2009. Peanut improvement: production of fertile hybrids and backcross progeny between *Arachis hypogaea* and *A. kretschmeri*. Food Security 1:457–462.
15.	1753-8254	Indian Growth and Development Review	Ramaswami B, Birthal PS and **Joshi PK**. 2009. Grower heterogeneity and the gains from contract farming: the case of Indian poultry. Indian Growth and Development Review 2:56-74.

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SNo.	ISSN No.	Journal Name	Journal Article
16.	0019-5014	Indian Journal of Agricultural Economics	Birthal PS, **Jha AK**, TIONGCO *MM* and *NARROD C*. 2009. Farm-level impacts of vertical coordination of the food supply chain: Evidence from contract farming of milk in India. Indian Journal of Agricultural Economics 64:484-496.
17.	0019-5014	Indian Journal of Agricultural Economics	Parthasarathy Rao P and **Joshi PK**. 2009. Does urbanization influence agricultural activities? A case study of Andhra Pradesh. Indian Journal of Agricultural Economics 64(3):401-408.
18.	0019-5014	Indian Journal of Agricultural Economics	Singh NP, **Shunmugam V and Garg S**. 2009. How efficient are futures market operations in mitigating price risk? An explorative analysis. Indian Journal of Agricultural Economics 64(3):324-332.
19.	971-2062	Indian Journal of Dryland Agricultural Research and Development	Ranga Rao GV, Sahrawat KL, Srinivasa Rao CH, Binitha Das, Kirankumar Reddy K, Bharath BS, Rameshwar Rao V, Murthy KVS and Wani SP. 2009. Insecticide residues in vegetable crops grown in Kothapalli watershed, Andhra Pradesh, India : A case study. Indian Journal of Dryland Agricultural Research and Development. 24(2):21-27.
20.		Indian Journal of Fertilisers	**Osman M**, Wani SP, **Balloli SS**, SREEDEVI TK, Srinivasa Rao Ch and D'Silva E. 2009. Pongamia seed cake as a valuable source of plant nutrients for sustainable agriculture. Indian Journal of Fertilisers 2:25–26, 29–31.
21.		Indian Journal of Fertilizers	Srinivasa Rao Ch, Wani SP, Sahrawat KL and Rajasekhararao B. 2009. Nutrient management strategies in participatory watersheds in semi arid India. Indian Journal of Fertilizers 5(12):113-116, 125-128.
22.	0367-973X	Indian Phytopathology	Thakur RP, Reddy BVS, Rao VP, **Agarkar GD**, **Solunke RB** and BHAT B. 2009. Evaluation of advanced sorghum breeding lines for grain mold resistance. Indian Phytopathology 62(2):163-170.
23.	0029-0610	Japanese Journal of Soil Science and Plant Nutrition	Takeshi Watanabe and Hiroaki Sumida. 2009. The latest research works in pedology in Asian countries 2. Experiment on the replicated rice straw compost application on paddy field and remediation of degraded environment on acid sulfate soil in the Mekong Delta. Japanese Journal of Soil Science and Plant Nutrition 80:288-296 (in Japanese).
24.	1542-7528 eISSN: 1542-7536	Journal of Crop Improvement	Singh Piara, Pathak P, Wani SP and Sahrawat KL. 2009. Integrated watershed management for increasing productivity and water-use efficiency in semi-arid tropical India. Journal of Crop Improvement 23(4):402-429.
25.	0954-1748 eISSN: 1099-1328	Journal of International Development	Birthal PS, **Singh H** and **Kumar S.** 2009. Agriculture, economic growth and regional disparities in India. Journal of International Development. (www.interscience.wiley.com) DOI: 10.1002/jid.1606.
26.	0970-2776	Journal of Oilseeds Research	ARUNA R and Nigam SN. 2009. Inheritance of fatty acid content and related quality traits in groundnut, *Arachis hypogaea* L. Journal of Oilseeds Research 26:10-17.
27.	0970-2776	Journal of Oilseeds Research	Divakara BN and Krishnamurthy R. 2009. Genetic variability, association and divergence studies in seed traits and oil content of *Madhuca latifolia* Macb. accessions. Journal of Oilseeds Research 26:686-689.
28.	0970-2776	Journal of Oilseeds Research	**JANILA P**, Ashok Kumar A, **Rajasekhar Reddy N, Sudhakar R** and **Ahmed SK**. 2009. Studies on host resistance to Botrytis grey rot in castor. Journal of Oilseeds Research. 26(1):35-40. (http://www.connectjournals.com/search_result.php?d_istid=2419)
29.	0970-2776	Journal of Oilseeds Research	Kiresur VR, **Melinamani VP**, Kulkarni VS, PUSHPA BHARATI and Yadav VS. 2009. Role of oilseeds in agricultural productivity, rural poverty and nutritional security nexus: A case study in Karnataka state, India". Journal of Oilseeds Research 26:696-700.

Bold=**NARES**; Underline=<u>ARI</u>; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

SNo.	ISSN No.	Journal Name	Journal Article
30.	2006-9758	Journal of Plant Breeding and Crop Science	Luo RH, Dalvi VA, Li YR and Saxena KB. 2009. A study on stigma receptivity of cytoplasmic-nuclear male-sterile lines of pigeonpea [*Cajanus cajan* (L.) Millsp.]. Journal of Plant Breeding and Crop Science 1(6):254-257.
31.	0019-638X	Journal of the Indian Society of Soil Science	**Bhattacharyya T, Ray SK, Pal DK, Chandran P, Mandal C** and Wani SP. 2009. Soil carbon stocks in India – Issues and priorities. 2009. Journal of the Indian Society of Soil Science 57(4):461-468.
32.	0019-638X	Journal of the Indian Society of Soil Science	Sahrawat KL. 2009. Organic nitrogen mineralization in submerged soils: The role of inorganic electron acceptors. Journal of the Indian Society of Soil Science 57:391-397.
33.	0730-2207	Plant Breeding Reviews	Reddy BVS, **Ramesh S**, SANJANA REDDY P and Ashok Kumar A. 2009. Genetic enhancement for drought tolerance in sorghum. Plant Breeding Reviews 31:189-222.
34.	0730-2207	Plant Breeding Reviews	Varshney RK, Thudi M, May GD and Jackson SA. 2009. Legume genomics and breeding. Plant Breeding Reviews 33:257-304.
35.	0049-8599	Quarterly Journal of International Agriculture	Asfaw S, *MITHOEFER D* and Waibel H. 2009. Investment in EU private food-safety standards compliance: Does it pay off for small-scale producers in Sub-Saharan Africa? Quarterly Journal of International Agriculture48(4):337-362.
36.	0049-8599	Quarterly Journal of International Agriculture	Birthal PS and **Joshi PK**. 2009. Efficiency and equity in contract farming: Evidence from a case study of dairying in India. Quarterly Journal of International Agriculture 48:363-378.
37.		Review of Agricultural and Environmental Studies	Simtowe Franklin, Manfred Zeller, Aliou Diagne. 2009. The impact of credit constraints on the adoption of hybrid maize in Malawi. Review of Agricultural and Environmental Studies 90(1):5-22. http://www.raestud.eu/pdf/005_022.pdf
38.	1870-0462	Tropical and Subtropical Agroecosystems	Van Rooyen A and Homann Kee Tui S. 2009. Promoting goat markets and technology development in semi-arid Zimbabwe for food security and income growth. Short Notes. Tropical and Subtropical Agroecosystems 11 (1):1-5.
39.	0047-245X	Journal of Food Distribution Research	Mausch K, *MITHOEFER D*, Asfaw S and Waibel H. 2008. Vegetable production in Kenya under EurepGAP standard: Is large "more beautiful" than small? Journal of Food Distribution Research 40(3): 115-129.
40.	0567-7572	Journal of Food Legumes	Sharma HC, Rajeev, V, Gaur, PM and Gowda, CLL. 2008. Potential for using morphological, biochemical, and molecular markers for resistance to insect pests in grain legumes. Journal of Food Legumes 21: 211-217.
41.		Journal of Hydrological Research and Development	Wani SP, SREEDEVI TK, Vamsidhar Reddy TS, **Venkateshvarlu B** and **Shambhu Prasad C**. 2008. Community watersheds for improved livelihoods through consortium approach in drought prone rainfed areas. Journal of Hydrological Research and Development 23:55-77.
42.	0048-6019	Journal of Research Punjab Agricultural University	**Sandhu JS, Singh Inderjit, Pal SS,** Gupta SK**, KAUR AJINDER, Brar SPS and Dhaliwal LS**. 2008. Mash 114: A high yielding and disease resistant variety of *kharif* mash. Journal of Research Punjab Agricultural University 45(3&4):230.
43.	0048-6019	Journal of Research Punjab Agricultural University	**Singh Sarvjeet, Virdi KS, Sidhu Navjot,** JOSHI NEHA, Gupta SKand **Nagi KS**.2008. PAU 1691: A new sunhemp variety for green manuring. Journal of Research Punjab Agricultural University 45:104.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

SNo.	ISSN No.	Journal Name	Journal Article
1.	3973-3094	E-Journal of SAT Agricultural Research	Ashok Kumar A, Belum VS Reddy, Ramaiah B, Sanjana Reddy P, Sahrawat KL and Upadhyaya HD. 2009. Genetic variability and plant character association of grain Fe and Zn in selected core collections of sorghum germplasm and breeding lines. E-Journal of SAT Agricultural Research. 7:1-4. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/SG702.pdf
2.	3973-3094	E-Journal of SAT Agricultural Research	Baskaran K, Hash CT, Senthilvel S, Bhasker Raj AG and Muthiah AR. 2009. SSR allele frequency changes in response to recurrent selection for pearl millet grain yield and other agronomic traits. E-Journal of SAT Agricultural Research. 7:1-8. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM701.pdf
3.	3973-3094	E-Journal of SAT Agricultural Research	Cooper P, Rao KPC, Singh P, Dimes J, Traore PS, Rao K, Dixit P and Twomlow SJ. 2009. Farming with current and future climate risk: Advancing a 'Hypothesis of Hope' for rainfed agriculture in the semi-arid tropics. E-Journal of SAT Agricultural Research. 7:1-19. http://ejournal.icrisat.org/Volume7/Agroecosystems/AES701.pdf
4.	3973-3094	E-Journal of SAT Agricultural Research	Gopal Reddy V, Upadhyaya HD, Gowda CLL and Sube Singh. 2009. Characterization of eastern African finger millet germplasm for qualitative and quantitative characters at ICRISAT. E-Journal of SAT Agricultural Research. 7:1-9. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM707.pdf
5.	3973-3094	E-Journal of SAT Agricultural Research	Manyasa EO, Silim SN and Christiansen JL. 2009. Variability patterns in Ugandan pigeonpea landraces. E-Journal of SAT Agricultural Research. 7:1-9. http://ejournal.icrisat.org/Volume7/Chickpea/PP701.pdf
6.	3973-3094	E-Journal of SAT Agricultural Research	Mula RP, Rai KN, Dangaria CJ and Kulkarni MP. 2009. Pearl millet as a postrainy cool season crop: case studies from Gujarat and Maharashtra, India. E-Journal of SAT Agricultural Research. 7:1-7. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM706.pdf
7.	3973-3094	E-Journal of SAT Agricultural Research	Nester Mashingaidze, Stephen J Twomlow and Lewis Hove. 2009. Crop and weed responses to residue retention and method of weeding in first two years of a hoe-based minimum tillage system in semi-arid Zimbabwe. E-Journal of SAT Agricultural Research. 7:1-11. http://ejournal.icrisat.org/Volume7/Agroecosystems/AES702.pdf
8.	3973-3094	E-Journal of SAT Agricultural Research	Rai KN, Gupta SK, Ranjana Bhattacharjee, Kulkarni VN, Singh AK and Rao AS. 2009. Morphological characteristics of ICRISAT-bred pearl millet hybrid seed parents. E-Journal of SAT Agricultural Research. 7:1-7. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM702.pdf
9.	3973-3094	E-Journal of SAT Agricultural Research	Rajan Sharma, Thakur RP, Rai KN, Gupta SK, Rao VP, Rao AS and Suresh Kumar. Identification of rust resistance in hybrid parents and advanced breeding lines of pearl Millet. E-Journal of SAT Agricultural Research. 7:1-4. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM704.pdf
10.	3973-3094	E-Journal of SAT Agricultural Research	Sanjana Reddy P, Belum VS Reddy and Ashok Kumar A. 2009. M 35-1 derived sorghum varieties for cultivation during the postrainy season. E-Journal of SAT Agricultural Research. 7: 1-4. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/SG701.pdf
11.	3973-3094	E-Journal of SAT Agricultural Research	Sreedevi TK, Wani SP, Kesava Rao AVR, Piara Singh and Irshad Ahmed. 2009. New science tools for managing community watersheds for enhancing impact. E-Journal of SAT Agricultural Research. 7:1-19. http://ejournal.icrisat.org/Volume7/Agroecosystems/AES703.pdf

| 12. | 3973-3094 | E-Journal of SAT Agricultural Research | Sreedevi TK, Wani SP, Mohammed Osman and Singh SN. 2009. Participatory research and development to evaluate Pongamia seed cake as source of plant nutrient in integrated watershed management. E-Journal of SAT Agricultural Research. 7:1-13. http://ejournal.icrisat.org/Volume7/Agroecosystems/AES704.pdf |
| 13. | 3973-3094 | E-Journal of SAT Agricultural Research | Thakur RP, Rajan Sharma, Rai KN, Gupta SK and Rao VP. 2009. Screening techniques and resistance sources for foliar blast in pearl millet. E-Journal of SAT Agricultural Research. 7:1-5. http://ejournal.icrisat.org/Volume7/Sorghum_Millets/PM705.pdf |

Book chapters

1.   Ashok S Alur, P Parthasarathy Rao**,** Ch Ravinder Reddy, Belum VS Reddy and CLL Gowda. 2009. Institutional innovations and market linkages for poverty alleviation and sustainable development of small scale farmers. Pages 87-102 *in* Agricultural Communication and Sustainable Development (Ambekar JB, ed.). Shruti publications, Jaipur, India. ISBN: 819052495X; ISBN-13: 9788190524957, 978-8190524957

2.   Audi P, NAGARAJAN L and Jones RB. 2009. Pigeonpea seed supply and diversity: a case study of local seed markets in Makueni district, eastern Kenya. Chapter 6 *in* Seed Trade in Rural Markets Implications for Crop Diversity and Agricultural Development (Leslie Lipper, Leigh Anderson C and Timothy J Dalton, eds.). CABI-FAO. ISBN: 9781844077854. http://www.earthscan.co.uk/?tabid=92750

3.   Birthal PS. 2009. Making contract carming work in smallholder agriculture: some success factors and policy. Pages 1-5 *in* Contract farming in India: A resource book (Gulati Ashok, Joshi PK and Landes M, eds.). Indian Council of Agricultural Research, New Delhi; International Food Policy Research Institute, Delhi office; and United States Department of Agriculture, Washington DC. Available at http://www.ncap.res.in/contract_%20farming/index.htm

4.   Birthal, PS and **Joshi PK**. 2009. Smallholder farmers' access to markets for high-value agricultural commodities in India. Pages 51- 60 *in* Case Studies in food policy for developing countries, vol. II (Pinstrup-Andersen Per and Cheng Fuzhi, eds.) Cornell University Press, Ithaca, New York.   ISBN: 978-0-8014-7555-9.

5.   **Datta S** and Varshney RK. 2009. Genomics Enabled Crop Improvement in Food Legumes. Pages 249-289 *in* Milestones in Food Legumes Research (Ali M and Kumar S, eds.). Indian Institute of Pulse Research (IIPR), Kanpur.

6.   **Gandhi BVJ**, BANTILAN MCS and Parthasarathy D. 2009. Vulnerability dynamics and HIV risk in the semi-arid tropics of rural Andhra Pradesh. Book Chapter in Vulnerability in Developing Countries (Wim Naude´, Amelia U Santos-Paulino and Mark McGillivray eds.). World Institute for Development Economics Research (UNU-WIDER), FIN-00160, Helsinki, Finland: United Nations University Press. 34 pp. ISBN-10: 9280811711; ISBN-13: 978-9280811711.

7.   Gaur PM, Tripathi S, Gowda CLL, Pande S, Sharma HC, Sharma KK, Kashiwagi J, Vadez V, Krishnamurthy L, Varshney RK, MALLIKARJUNA N and Hoisington DA. 2009. International Efforts in Chickpea Improvement. Pages 359-377 *in* Legumes for Ecological Sustainability (Ali M, Gupta S, Basu PS and Nimuddin, eds.). Kanpur, India: Indian Society of Pulses Research and Development.

8.   Gowda CLL, Serraj R, Srinivasan G, Chauhan YS, Reddy BVS, Rai KN, Nigam SN, Gaur PM, Reddy LJ, Dwivedi SL, Upadhyaya HD, Zaidi PH, **Rai HK**, **Maniselvan P**, Folkerstma R and NALINI M. 2009. Opportunities for improving crop water productivity through genetic enhancement of dryland crops. Pages 133-163 *in* Rainfed Agriculture: Unlocking the Potential (Wani SP, Rockström J and Oweis T, eds). CAB International, Nosworthy Way, Wallingford, Oxfordshire OX10 8DE, United Kingdom. ISBN: 978-1-84593-389-0.

9.   Gowda CLL, Tripathi S and Gaur PM. 2009. Role of grain legumes in improving income and livelihoods of farmers of rainfed areas. Pages 1-7 *in* Legumes for Ecological Sustainability (Ali M, Gupta S, Basu PS and Nimuddin, eds.). Kanpur, India: Indian Society of Pulses Research and Development.

10.   Haussmann BIG and Parzies HK. 2009. Methodologies for generating variability. Part 1. Use of Genetic Resources in Plant Breeding. Chapter 5, Pages 107–128 *in* Participatory Plant Breeding (Ceccarelli S, Guimarães EP, Weltzien E and Rajendran PG, eds.). FAO, Rome, Italy. ISBN: 9789251063828.

11.   JAYASHREE B and Dave Hoisington. 2009. Bioinformatics tools for crop research and breeding *in* Molecular Techniques in Crop Improvement (Jain SM and Brar, eds.). Kluwer academic Publishers. ISBN: 978-90-481-2966-9 (Print); 978-90-481-2967-6 (Online) http://www.springerlink.com/content/p570675017150512/

12.   **Joshi PK, Jha AK**, Wani SP and SREEDEVI TK. 2009. Scaling-out community watershed management for multiple benefits in rainfed areas. Pages 258-275 *in* Rain-fed agriculture: Unlocking the Potential. (Wani SP, John Rockstrom and Theib Oweis, eds.). Comprehensive Assessment of Water Management in Agriculture Series, CAB International, Wallingford, UK. ISBN: 978-1-84593-389-0.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

13. Keatinge JDH, Gaur PM, Saxena KB, Silim S, Wani SP, Jones RB, Siambi M, Waliyar F, Gowda CLL and Ntare BR. 2009. Diversification of cropping systems with food legumes in the semi-arid tropics. Pages 15-28 *in* Legumes for Ecological Sustainability (Ali M, Gupta S, Basu PS and Nimuddin, eds.). Kanpur, India: Indian Society of Pulses Research and Development.

14. Laxmipathi Gowda CL, Parthasarathy Rao P, Tripathi S, Gaur PM and **Deshmukh RB**. 2009. Regional shift in chickpea production in India. Pages 21-35 *in* Milestones in Food Legumes Research (Masood Ali and Shiv Kumar, eds.). Indian Institute of Pulses Research, Kanpur 208 024, Kanpur, Uttar Pradesh, India.

15. Laxmipathi Gowda CL, Tripathi S and Gaur PM. 2009. Global perspective of grain legume research. Pages 6-12 *in* International Conference on Grain Legumes: Quality Improvement, Value Addition and Trade, 14-16 Feb 2009, Indian Institute of Pulses Research, Kanpur, India.

16. MATI BM. 2009. Optimizing agricultural water management for the green revolution in Africa. *In* Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts (Bationo A, Waswa BS, Okeyo JM and Maina F, eds.). Springer. ISBN: 978-90-481-2541-8.

17. Nigam SN. 2009. Crop improvement strategies in groundnut. Pages 1-12 *in* Vegetable oils scenario: Approaches to meet the growing demands (Hegde DM, ed.). Indian Society of Oilseeds Research, Hyderabad.

18. Nigam SN. 2009. Expansion of groundnut cultivation in southeast Asia: A case study of Vietnam. Pages 73-81 *in* Milestones in Food Legumes Research (Masood Ali and Shiv Kumar, eds.). Indian Institute of Pulses Research, Kanpur, India. 324 p.

19. Osiru MO, Monyo ES, Waliyar F, **CHINYAMUNYAMU B, Mponda O** and Siambi M. 2009. Participatory development of improved groundnut varieties for East and Southern Africa. Volume 1, Issue 1, Pages 35 - 40 *in* Agricultural Innovations for Sustainable Development. Contributions from the Finalists of the African Youth in Science Competition. Published by the African Technology Policy Studies Network, Nairobi Kenya. ISBN: 978 9966-7434-4-8. Website: http://www.atpsnet.org/pubs/Agri_Innovations_v1.pdf

20. Pathak P, Sahrawat KL, Wani SP, Sachan RC and Sudi R. 2009. Opportunities for water harvesting and supplemental irrigation for improving rain-fed agriculture in semi-arid areas. Pages 197-221 *in* Rain-fed agriculture: Unlocking the potential. (Wani SP, John Rockstrom and Theib Oweis, eds.). Comprehensive Assessment of Water Management in Agriculture Series, CAB International, Wallingford, UK. ISBN 978-1-84593-389-0.

21. Rattunde F, VOM BROCKE K, WELTZIEN E and HAUSSMANN BIG. 2009. Selection methods. Part 4, Developing open-pollinated varieties using recurrent selection methods. Pages 259-273 *in* Plant Breeding and Farmer Participation (Ceccarelli S, Guimaraes EP and Weltzien E, eds.). FAO, Rome. ISBN 978-92-5-106382-8.

22. Saxena KB. 2009. Evolution of hybrid breeding technology in pigeonpea. Pages 82-114 *in* Milestone in Food Legume Research (Masood Ali and Shiv Kumar, eds.). Published in IIPR, Kanpur 208 024. Milestones in Food Legume Research Conference 2009.

23. Sharma HC and Dhillon, MK. 2009. Recent advances in application biotechnological tools for pest management. Pages 1-12 *in* National Symposium on Biotechnological and Biorational Approaches for Pest Management in Agriculture, 6 – 7 Nov 2009. University of Agricultural sciences, Dharwad, Karnataka, India.

24. *Shiv Kumar,* **Sandhu JS**, Gupta SK, **Dikshit HK** and **Gupta Sanjeev**. 2009. Broadening genetic base of pulse crops: present status and future strategies. Pages 342-358 i*n* Legumes for Ecological Sustainability. Published by Indian Society of Pulses Research and Development, IIPR, Kanpur, India. http://www.iipr.res.in/internconfleg.pdf

25. **Singh KN,** Rathore A**, Tripathi AK, Rao AS, Khan S** and **Singh B**. 2009. Use of geographic information system, remote sensing and global positioning system in the application of precise fertilizer to maintain soil productivity of the farmers fields. Pages 183-195 *in* New Technology for rural development having potential of commercialization (Shukla JP, Mandal DP, Jain PK and Shukla A, eds.). Allied Publishers Pvt. Ltd., New Delhi, India.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

26.   Singh P, **Aggarwal PK**, **Bhatia VS**, Murty MVR, *Pala M, Oweis T, Benli B*, Rao KPC and Wani SP. 2009. Yield gap analysis: modelling of achievable yields at farm level. Pages 81-123 *in* Unlocking the Potential. Comprehensive Assessment of Water Management in Agriculture (Wani SP, Rockström J and Oweis T, eds.). London, UK: CABI Publishing.

27.   SREEDEVI TK and Wani SP. 2009. Integrated farm management practices and up-scaling the impact for increased productivity of rainfed systems. Pages 222-257 *in* Rain-fed agriculture: Unlocking the Potential (Wani SP, Rockström J and Oweis T, eds.) Comprehensive Assessment of Water Management in Agriculture Series, CAB International, Wallingford, UK. ISBN: 978-1-84593-389-0.

28.   Traoré PCS, Bostick WM, Jones JW and Bado BV. 2009. Simplifying RothC for biomass data assimilation in C sequestration contracts. Volumes 2 *in* Innovations as key to the green revolution in Africa: Exploring the Scientific Facts (Bationo A, Waswa BS, Okeyo JM and Maina F, eds.). Hardcover, Springer. 1850 pp. ISBN: 978-90-481-2541-8.

29.   Upadhyaya HD, Dwivedi SL, Gowda CLL, Singh S, and Reedy KN. 2009. Enhancing the value of plant genetic resources towards their global utilization in improving the genetic potential of chickpea, pigeonpea and groundnut crops. Pages 178-205 *in* Milestones in Food Legumes Research (Masood Ali and Shiv Kumar, eds.). IIPR Kanpur.

30.   Varshney RK, Hoisington DA, **NAYAK SN** and Graner A. 2009. Molecular plant breeding: methodology and achievements. Pages 283-304 *in* Methods in Molecular Biology: Plant Genomics (Somers D, Langridge P and Gustafson PJ, eds.). The Humana Press, Totowa, NJ, USA.

31.   Varshney RK. 2009. Gene-based marker systems in plants: high throughput approaches for discovery and genotyping. Volume II, Pages 119-142 *in* Molecular Techniques in Crop Improvement (Jain SM and Brar DS, eds.). Springer, The Netherlands. ISBN: 978-90-481-2966-9 (Print) 978-90-481-2967-6 (Online). http://www.springerlink.com/content/w27441h835h2508l/

32.   Waliyar F. 2009. Afghanistan Agriculture: Current status and future needs. Pages 46-58 *in* Converting desert in to oasis (Yadav JSP, Singh RK and Gupta VP, eds.). The International Crops Research institute for the Semi Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India. ISBN: 1933699418; ISBN-13: 9781933699417, 978-1933699417. http://www.flipkart.com/converting-deserts-into-oasis-yadav/1933699418-n2x3fvrkhc

33.   Wani SP, SREEDEVI TK, **Rockström J** and **Ramakrishna YS**. 2009. Rain-fed agriculture - Past trend and future prospects. Pages 1-35 *in* Rain-fed agriculture: Unlocking the Potential (Wani SP, Rockström J and Oweis T, eds.). Comprehensive Assessment of Water Management in Agriculture Series. CAB International, Wallingford, UK. ISBN 978-1-84593-389-0.

34.   Wani SP, SREEDEVI TK, **Yin Dixin, Thawilkal Wangkahart** and **Thang NV**. 2009. Conservation of natural resources and their efficient use for sustainable development in Asia. 2009. Pages 121-145 *in* Rainfed Agriculture in India: Perspectives and Challenges (Surjit Singh and Rathore MS, eds.). Institute of Development Studies, Jaipur. ISBN-13: 978-8-13160-311-6. http://www.flipkart.com/rainfed-agriculture-india-surjit-singh/8131603113-tu23f9a9m8

35.   WELTZIEN E and CHRISTINCK A. 2009. Methodologies for priority setting. Pages 75-105 *in* Plant Breeding and Farmer Participation (Ceccarelli S, Guimaraes EP and Weltzien E, eds.). FAO, Rome. ISBN 9789251063828.

36.   COYNE CJ, *Baum M*, **Sharma PC**, Gaur PM, Muehlbauer FJ, McPhee KE, Timmerman-Vaughan GM, Pilet-Nayel M-L, Brown AF, and McGee RJ. 2008 (Published in 2009). Application of molecular markers in food legumes breeding. Volume 1, Pages 258-276 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed.). New Delhi, India: Indian Society of genetics and Plant Breeding.

37.   Gaur PM, Kumar J, Gowda CLL, Pande S, Siddique KHM, Khan TN, Warkentin, TD, Chaturvedi SK, THAN AM and Ketema D. 2008 (Published in 2009). Breeding chickpea for early phenology: perspectives, progress and prospects. Volume 2, Pages 39-48 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed.): New Delhi, India: Indian Society of genetics and Plant Breeding.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

38. Hash CT and Senthilvel S. 2008. DNA markers and marker-assisted selection – Application of theory. Pages 180-201 *in* Sorghum Improvement in the New Millennium. (Reddy Belum VS, Ramesh S, Ashok Kumar A and Gowda CLL, eds.). International Crops Research Institute for the Semi-Arid Tropics, Patancheru – 502324, India. Reviewed by Dr Ramesh S, University of Agricultural Sciences, Bangalore. ISBN:978-92-9066-512-0.

39. Kashiwagi J, Krishnamurthy L, Upadhyaya HD, Chandra S and Gaur PM. 2008. Genetic control of drought avoidance root traits in chickpea (*C. arietinum* L.). Pages 584-588 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed.). Proceedings of the Fourth International Food Legumes Research (IFLRC IV), Oct 18-22, 2005, New Delhi, India.

40. Monyo E, Osiru M, Rusike J, Mgonja M, **Mponda O** and Kadyampakeni D. 2008. Mother and baby trials and farmer field schools for technology targeting and scaling-up/out. Pages 55-59 *in* Improving Food Security and Nutrition in Malawi and Tanzania through Research on Edible Legumes. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 96 pp. ISBN: 978-92-9066-515-1

41. Monyo ES, Osiru MO, **Mponda O** and **CHINYAMUNYAMU B**. 2008.Researchable challenges and opportunities in groundnuts for smallholder farmers in Eastern and Southern Africa-A regional perspective. Pages 7- 22 *in* Improving Food Security and Nutrition in Malawi and Tanzania through Research on Edible Legumes. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 96 pp. ISBN: 978-92-9066-515-1

42. NAMITA SRIVASTAVA, Vadez V, Krishnamurthy L, Saxena KB, Nigam SN and RUPAKULA A. 2008. Standardization of a screening technique for salinity tolerance in groundnut (*Arachis hypogaea*) and pigeonpea (*Cajanus cajan*). Pages 575-583 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed.). Proceedings of the Fourth International Food Legumes Research (IFLRC IV), Oct 18-22, 2005, New Delhi, India.

43. Rao KPC. 2008. WTO and issues in agricultural trade. Chapter 13, Pages 287-306 *in* The WTO at the crossroads (Paramita Dasgupta, ed.). Concept Publishing Company, New Delhi. Jain Book Agency, India. ISBN: 8180694437; ISBN-13: 9788180694431, 978-8180694431. http://www.flipkart.com/wto-crossroads-paramita-dasgupta/8180694437-6v23f9135o

44. Saxena NP, *Saxena MC*, **Johansen C**, **RENU-KHANNA CHOPRA**, Krishnamurthy L and Raka Sharan. 2008. Characterization of drought and adaptation of cool season food legumes to water-limiting environments. Pages 661-677 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed). Proceedings of the Fourth International Food Legumes Research (IFLRC IV), Oct 18-22, 2005, New Delhi, India.

45. Sharma HC, Clement SL, Ridsdill-Smith TJ, Ranga Rao GV, *El Bouhssini M,* **Ujagir R, Srivastava CP** and Miles M. 2008. Insect pest management in food legumes: The future strategies. Volume 1, pages 522 – 544 *in* Food Legumes for Nutritional Security and Sustainable Agriculture, Proceedings of the IVth International Food Legumes Research Conference (Kharkwal MC, ed.). New Delhi, India: Indian Society of Genetics and Plant Breeding.

46. SREELATHA G, Sharma HC, **Manohar Rao D**, Royer M and Sharma KK. 2008. Genetic transformation of pigeonpea [*Cajanus cajan* (L.) Millsp.) with *Bt cry1Ac* gene and the evaluation of transgenic plants for resistance to *Helicoverpa armigera*. Volume 2, pages 185-196 *in* Food Legumes for Nutritional Security and Sustainable Agriculture, Proceedings of the IVth International Food Legumes Research Conference (Kharkwal MC, ed.). New Delhi, India: Indian Society of Genetics and Plant Breeding.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

Books and Journal Volumes

1. *Ceccarelli S*, <u>Guimaraes EP</u>, and WELTZIEN E. (eds.). 2009. Plant breeding and farmer participation, FAO, Rome. 671 pp. ISBN: 978-92-5-106382-8.

2. <u>CHRISTINCK A</u>, WELTZIEN E, and <u>HOFFMANN V</u>. (eds). 2009. Définition d'objective de sélection et création de systèmes semenciers en collaboration avec les paysans. Un manuel pratique pour les projets de sélection participative des plantes. Margraf Publishers, Weikersheim, Germany et Centre technique de coopération agricole et rurale (CTA) Wageningen, Pays-Bas. 196 pp.

3. **Jacob Kijne, Jennie Barron, Holger Hoff, Johan Rockström, Louise Karlberg, John Gowing,** Wani SP and **Dennis Wichelns**. 2009. Opportunities to increase water productivity in agriculture with special reference to Africa and South Asia. Stockholm Environment Institute Project Report 2009. Sweden. 48 pp. <u>http://sei-international.org/mediamanager/documents/Publications/Water-sanitation/opportunitiestoincreasewaterprod2009.pdf</u>

4. **Khairwal IS**, Rai KN, **Yadav OP**, **Rajpurohit BS** and **Negi S**. 2009. Pearl millet cultivars: Seeds of choice. All India Coordinated Pearl Millet Improvement Project, Indian Council of Agricultural Research, Mandor, Jodhpur, India. 36pp.

5. **Khairwal IS**, SATYAVATHI T, **Yadav OP**, Rai KN, **Rajpurohit BS** and **Yadavv SK**. 2009. Trait-specific germplasm sources in pearl millet. All India Coordinated Pearl Millet Improvement Project, Indian Council of Agricultural Research, Mandor, Jodhpur, India. 68pp.

6. Osiru MO, Monyo ES, Waliyar F, **CHINYAMUNYAMU B, Mponda O** and Siambi M. 2009. Agricultural innovations for sustainable development. Contributions from the finalists of the African youth in science Competition. Volume 1. Issue 1. Published by the African Technology Policy Studies Network, Nairobi Kenya. 2009. 123pp. ISBN: 978-9966-7434-4-8. <u>http://www.atpsnet.org/pubs/Agri_Innovations_v1.pdf</u>

7. **Prasada Rao GSLHV**, Kesava Rao AVR, **Krishnakumar K** and **Gopakumar CS**. 2009. Climate variability and food security. All India Coordinated Research Project on Agrometeorology and Centre for Climate Change Research, Kerala Agricultural University, Vellanikkara, Thrissur. 73 pp.

8. Sharma HC. 2009. Applications of biotechnology in pest management and ecological sustainability. Boca Raton, USA: CRC Press, Taylor and Francis. 526 pp.

9. Van de Steeg J, Hererro M, Kinyagi J, Thornton PK, Rao KPC*, **Stern R** and Cooper P. 2009. The influence of climate variability and climate change on the agricultural sector in East and central Africa – Sensitizing the ASARECA strategic plan to climate change. Research Report 22, ILRI. 85pp. ISBN 92-9146-238-1.

10. Wani SP, **Rockström J** and **Oweis T** (eds.). 2009. Rain-fed agriculture: Unlocking the Potential. Comprehensive assessment of water management in agriculture series, CAB International, Wallingford, UK. 325 pp. ISBN: 978-1-84593-389-0.

11. Amita Shah, Wani SP and SREEDEVI TK (eds.). 2009. Impact of watershed management on women and vulnerable groups. Proceedings of the Workshop on Comprehensive Assessment of Watershed Programs in India, 25 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 184 pp. ISBN: 978-92-9066-523-6. CPE 166.

12. Parthasarathy Rao P, Ravinder Reddy Ch, Ashok S Alur, Reddy BVS and Gowda CLLL. 2009. Impacts of CFC-FAO-ICRISAT. Livelihood Improvement in Asia region-I-India. International Crops Research Institute for the Semi Arid Tropics. Patancheru-502324, Andhra Pradesh. 128pp.

13. Sharma HC and Dhillon MK (eds.). 2009. Proceedings of the Symposium on biosafety and environmental impact of genetically modified organisms and conventional technologies for pest management, 20-21 November 2009. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India. 59 pp.

Bold=**NARES**; Underline=<u>ARI</u>; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

14. Thakur RP, Gunjotikar GA and Rao VP. 2009. Safe movement of ICRISAT's seed crops germplasm. Information Bulletin No.81 (Etienne Duveiller, Plant Pathologist, CIMMYT, ed.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 176 pp.

15. Wani SP, **Venkateswarlu B**, Sahrawat KL, Rao KV and Ramarkishna YS (eds.). 2009. Best-bet Options for integrated watershed management. Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 312 pp. ISBN: 978-92-9066-526-7: CPE 167.

16. Asfaw S. 2008. Global agrifood supply chain, EU food-safety standards and African small-scale producers: The case of high-value horticultural export from Kenya (Hermann Waibel and Ulrike Grote, eds.). Pesticide Policy Project Publication Series No. 13. ISBN: 3-934373-14-3.

17. Monyo ES, Osiru MO, Kadyampakeni D, **Mponda O** and **CHINYAMUNYAMU B**. (eds.). 2008. Improving food security and nutrition in Malawi and Tanzania through research on edible legumes. Proceedings of Stakeholder Workshops on Groundnut Production in Malawi and Tanzania held 1-2 March and 13 April 2007, Lilongwe (Malawi) and Mtwara (Tanzania). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 96 pp. ISBN: 978-92-9066-515-1.

18. Reddy Belum VS, Ramesh S, Ashok Kumar A and Gowda CLL. 2008. Sorghum Improvement in the new millennium. International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502324, India. Reviewed by Dr S Ramesh, University of Agricultural Sciences, Bangalore. ISBN: 978-92-9066-512-0.

Conference Proceedings

1.   Adekambi Souléïmane Adéyèmi, Aliou Diagne, Franklin Simtowe and Gauthier Biaou. 2009. The impact of agricultural technology adoption on poverty: The case of Nerica rice varieties in Benin: Conference for the International Association for Agricultural Economists-Beijing-China.
http://ageconsearch.umn.edu/bitstream/51645/2/473.pdf

2.   Aliou Diagne, Marie-Josée Sogbossi , Franklin Simtowe**,** Sékou Diawara , and Abdoulaye Sadio Diallo Alpha Bacar Barry. 2009. Estimation of actual and potential adoption rates and determinants of a new technology not universally known in the population: The case of Nerica rice varieties in Guinea: The International Association for Agricultural Economists (IAAE)- Beijing-China.
http://ageconsearch.umn.edu/bitstream/51644/2/354.pdf

3.   *Anandan, S,* Sharma KK and *Blümmel M.* 2009. Biotechnology of food-feed crops for improving quantity and quality of livestock feeds. Pages 82-85 *in* Proceedings of the Animal Nutrition Association World Conference on Animal Nutrition: Preparedness to Combat Challenges held at New Delhi, India, 14-17 February 2009.

4.   Anantha KH, Wani SP and Sreedevi TK 2009. Agriculture and allied micro-enterprise for livelihood opportunities. Pages 271-290 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162.
http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

5.   Anantha KH, Wani SP and SREEDEVI TK 2009. Baseline socio-economic characterization of watersheds. Pages 27-39 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162.
http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

6.   Asfaw S, MITHOEFER D AND Waibel H. 2009. Food-safety standards and farmers health: Evidence from Kenyan's export vegetable growers. The International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009. 19pp.
http://ageconsearch.umn.edu/bitstream/49928/2/IAAE-chinarev.pdf

7.   Ashok Kumar A, *Blümmel M*, **Rao SS, Seetharama N**, Srinivasa Rao P, Sanjana Reddy P and Reddy BVS. 2009. Evaluation of sweet sorghums for agronomic and fodder quality traits. Forage Symposium-2009 on "Emerging Trends in Forage Research and Livestock Production", 16-17 February 2009, Jaisalmer, Rajasthan, India.18-19 pp.

8.   Birthal PS and Parthasarathy Rao P. 2009. Making livestock revolution work for the poor in integrated mixed farming systems. Volume 1 Lead Papers, Pages 144-149 *in* Animal Nutrition – Preparedness to Combat Challenges. Proceedings of Animal Nutrition Association World Conference, 14-17 February 2009, New Delhi, India.

9.   *Blümmel M*, **Seetharama N**, Prasad KVSV, Ramakrishna Ch, Khan AA, Anandan S, Hash CT, Reddy B, Nigam S and Vadez V. 2009. Food-feed crop research and multidimensional crop improvement in India. Volume I, Lead Papers , Pages 17-19 *in* Proceedings of Animal Nutrition Association World Conference, 14-17 Feb 2009, New Delhi, India.

10.   **Diallo C** and WELTZIEN E. 2009. Different variety types of sorghum for farmers in the Northern Sudanian zone of Mali. Highlight paper at the Colloquium Mobilizing Regional Diversity for Pearl Millet and Sorghum Intensification in West Africa held from 5 to 9 May 2009 at Niamey, Niger. Copies available with e.weltzien@icrsatml.org or b.ig.haussmann@cgiar.org, and on the website
http://www.fidafrique.net/IMG/pdf/Different_variety_types_of_sorghum_for_farmers_in_the_northern_ _Sudanian_zone_of_Mali.pdf

11.   Diarra B, Waliyar F, Kodio O, Konaté D and Traore A. 2009. Test en milieu paysan de greniers traditionnels améliorés pour la conservation de l'arachide dans la région de Kayes. Pages 1-28 *in* Fourth International Conference of the Peanut Research Community on *Advances in Arachis through Genomics and Biotechnology*

(AAGB-2009) & West and Central Africa Regional Peanut Workshop, 19-22 October 2009, Bamako, Mali.

12. Dimes J and **du Toit P**. 2009. Quantifying water productivity in rain-fed cropping systems in Limpopo Province, RSA. Pages 113-124 *in* Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers (Humphreys E and Bayot RS, eds.). Proceedings CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September, 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 311pp. ISBN: 978-92-990053-4-7.

13. Dimes J, Cooper P and Rao KPC. 2009. Climate change impact on crop productivity in the semi-arid tropics of Zimbabwe in the 21st Century.   Pages 189-198 *in* Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. (Humphreys E and Bayot RS, eds.). Proceedings CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September, 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 311pp. ISBN: 978-92-990053-4-7.

14. Dorothy Tembo and Simtowe Franklin. 2009. The effects of market accessibility on household food security: Evidence from Malawi. The conference on Biophysical and Socio-economic Frame Conditions for the Sustainable Management of Natural Resources -Tropentag, October 6-8, 2009, Hamburgv. www.tropentag.de/2009/abstracts/full/420.pdf

15. Dwivedi SL, Upadhyaya HD and Gowda CLL. 2009. Approaches to enhance the value of genetic resources in crop improvement. Pages 68-74 *in* Strengthening Information on Plant Genetic Resources in Asia (Vaughman D, ed.). FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

16. Fatondji D, Bationo A, Tabo T, Jones JW, Adamou A and Hassane O. 2009. Water use and yield of millet under the zai system: understanding the processes using simulation. Pages 125-146 *in* Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers (Humphreys E and Bayot RS, eds.). Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. ISBN: 978-92-990053-4-7.

17. Gaur PM, Tripathi S, Gowda CLL, Pande S, Sharma HC, Sharma KK, Kashiwagi J, Vadez V, Krishnamurthy L, Varshney RK, Mallikarjuna N and Hoisington DA. 2009. International efforts in chickpea improvement. Pages 359-377 *in* Legumes for Ecological Sustainability: Proceedings of the National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities (Masood Ali, Sanjeev Gupta, Basu, PS and Naimuddin, eds.). 3-5 November 2007, Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

18. Guntur SV, Hossain AKMZ, Nakahara K, Ishikawa T, Yanbuaban M, Yoshihashi T, Ono H, Yoshida M, Hash CT, Upadhyaya H, Srinivas P, Reddy BS, Sahrawat KL and Ito O. 2009. Biological nitrification inhibition (BNI) potential in sorghum. The Proceedings of the International Plant Nutrition Colloquium XVI, Plant Nutrition for Sustainable Development and Global Health, August 26th – 30th, Sacramento, California, USA. Paper 1175. http://repositories.cdlib.org/ipnc/xvi/1175

19. Keatinge JDH, Gaur PM, Saxena KB, Silim S, Wani SP, Jones RB, Siambi M, Waliyar F, Gowda CLL and Ntare BR. 2009. Diversification of cropping systems with food legumes in the semi-arid tropics. Pages 15-28 *in* Legumes for Ecological Sustainability: Proceedings of the National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities (Masood Ali, Sanjeev Gupta, Basu, PS and Naimuddin, eds.). 3-5 November 2007, Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

20. Keatinge JDH, Waliyar F, Jamnadass RH, Moustafa A, Andrade M, Drechsel P, Hughes J d'A, Palchamy Kardirvel and Luther K. 2009. Re-learning old lessons for the future food: by bread alone no longer – diversifying diets with fruit and vegetables. Science Forum 2009, Wageningen, Netherlands 16-17 June. http://www.scienceforum2009.nl/Portals/11/2Keatingetal.pdf

21. Kiragu GM, Home PG, MATI BM and Gathenya J M. 2009. Pages 73-89 *in* Assessment of suspended sediment pollution of Upper Mara River, Kenya. International I.E.K. Conference on "Food, Water and Energy Security: Engineering Challenges of the 21st Century" on 22nd to 24th April, 2009. Institution of Engineers of Kenya, Nairobi.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

22. Kiresur VR, **Melinamani VP**, Kulkarni VS, PUSHPA BHARATI and VS Yadav. 2009. Role of oilseeds in agricultural productivity, rural poverty and nutritional security nexus: A Case Study in Karnataka State, India. Page 696-700 *in* the National Symposium on "Vegetable Oils Scenario: Approaches to Meet the Growing Demands", Indian Society of Oilseeds Research, Hyderabad at Directorate of Oilseeds Research, Hyderabad, during 29-31 January 2009.

23. Laxmipathi Gowda CL, Shailesh Tripathi and Gaur PM. 2009. Role of grain legumes in improving income and livelihoods of farmers of rainfed areas. Pages 1-14 *in* Legumes for Ecological Sustainability: Proceedings of the National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities (Masood Ali, Sanjeev Gupta, Basu, PS and Naimuddin, eds.). 3-5 November 2007, Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

24. MATI BM. 2009. Improving the productivity of drylands through small holders interventions in agricultural water management in Eastern and Southern Africa. Pages 111-128 *in* Lead Papers: International Conference on: Nurturing Arid Zones for People and the Environment (Tripathi RS, Kaul RK, Praveen-Kumar, Amal Kar and NV Patil, eds.). Jodhpur India. Arid Zone Research Association of India and Central Arid Zone Research Institute, Jodhpur India.

25. Monyo ES, **Mponda O**, **NAKHUMWA C**, **Kafiriti E., CHINYAMUNYAMU B,** Munthali W and Siambi M.2009. Developing short-and medium-duration groundnut varieties with improved yield performance, acceptable market traits and resistance to foliar diseases - project overview, progress report and outlook for phase II. The Third Meeting of Southern Africa Community of Practice (SAf COP3) 21 – 25 September, 2009, Millennium Hotel – Bagamoyo, Tanzania. http://mcknight.ccrp.cornell.edu/participants/safcop3_09/safcop3_09.html

26. Monyo ES, Osiru M, Sichone E, Msere H, Loga C, **Chinyamunyamu B,** Waliyar F and Siambi M. 2009. Aflatoxin occurrence and distribution in Malawi. Fourth International Conference of the Peanut Research Community on Advances in Arachis through Genomics and Biotechnology (AAGB-2009) & West and Central Africa Regional Peanut Workshop, 19-22 October 2009, Bamako, Mali. 27 pp.

27. Ndjeunga J, Waliyar F and Ntare B. 2009. Assessing the cost effectiveness of pre-harvest options to control aflatoxin in groundnut in West Africa: Case of Mali. Pages 20 *in* Fourth International Conference of the Peanut Research Community on *Advances in Arachis through Genomics and Biotechnology* (AAGB-2009) & West and Central Africa Regional Peanut Workshop, 19-22 October 2009, Bamako, Mali.

28. Parthasarthy Rao P, **Joshi PK,** Shravan Kumar and GANGULY K. 2009. Marketing and policy initiatives to promote agricultural diversification in Andhra Pradesh. Proceedings of Agribusiness potential of Andhra Pradesh. Pages 270-289 *in* Indian Society of Agricultural Marketing, Nagpur, India.

29. Pathak P, Mishra PK, Rao KV, Wani SP and Sudi R. 2009. Best-Bet Options on soil and water conservation. Pages 75-94 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

30. Peter Bezkorowajnyj and Wani SP. 2009. Crop-livestock linkages in watershed villages of Andhra Pradesh. Pages 191-204 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

31. Piara Singh, Pathak P, Wani SP and Sahrawat KL. 2009. Integrated water resource management for increasing productivity and water use efficiency in the rain-fed areas of India. Pages 177-190 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

32.   **Prasada Rao GSLHV**, Kesava Rao AVR, **Krishnakumar K** and **Gopakumar CS**. 2009. Climate change projections and impacts on plantations in Kerala. Pages 23-36 *in* Proceedings of the National Seminar on climate change adaptation strategies in Agriculture and allied sectors (Prasada Rao GSLHV, Kesava Rao AVR and Alexander D, eds.) held at Thrissur, 03-04 December 2009. Centre for Climate Change Research, Kerala Agricultural University, Vellanikkara, Thrissur, India.

33.   **Raghunadha Reddy G, Gaurava Reddy K** and Parthasarthy Rao P. 2009. Agribusiness potential of grain sorghum in Andhra Pradesh. Proceedings of Agribusiness potential of Andhra Pradesh. Pages 13-28 *in* Indian Society of Agricultural Marketing, Nagpur, India.

34.   Ranga Rao GV and Gopalakrishnan S. 2009. Bio-pesticides research at ICRISAT: A consortium model. Pages 1-27 *in* Proceedings of Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture, Organized by Asia-Pacific Association of Agricultural Research Institutions (APAARI) & Council of Agriculture, Taipei (COA), Taiwan Agricultural Research Institute, Taichung, 27 – 29 October 2009.

35.   Ranga Rao GV, Desai S, Rupela OP, Krisnappa K and Wani SP and 2009. Integrated pest management options for better crop production. Pages 155-175 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

36.   **Rao VUM**, Manikandan N, Singh NP, BANTILAN MCS, **Satyanarayana T, Rao AVMS** and **Rao GGSN**. 2009. Trends of heavy rainfall events in Anathapur and Mahabubnagar districts of Andhra Pradesh. Pages 71-79 *in* Proceedings of fourth National Seminar on Agrometeorology – Needs, Approaches and Linkages for Rural Development. November 26-27, 2009. CCS Haryana Agricultural University, Hisar.

37.   Rattunde HFW. 2009. Increasing NARS access to regional sorghum diversity: germplasm collection, exchange and characterisation. Colloquium on Mobilizing Regional Diversity for Pearl Millet and Sorghum Intensification in West Africa. 5 to 9 May 2009 Niamey, Niger. Copies available with e.weltzien@icrsatml.org or b.ig(dot)haussmann(at)cgiar(dot)org, and on the website:http://www.fidafrique.net/IMG/pdf/Increasing_NARS_access_to_Regional_Sorghum_Diversity_Germplasm_Collection_Exchange_and_Characterisation.pdf

38.   Reddy BVS, Srinivas Rao P, Ashok Kumar A, SANJANA REDDY P, Parthasarthy Rao P, Sharma KK, *Blümmel M* and Ravinder Reddy Ch. 2009. Sweet sorghum as a biofuel: Where are we now? Pages 191-202 *in* Proceeding of the 6th International Biofuels Conference, 4-5 March 2009, New Delhi, India.

39.   Saxena KB, Srivastava RK, **Wanjari KB**, Gowda CLL, **Sarode SV**, **Singh IP**, **Shiv Kumar**, Kumar RV and **Masood Ali**. 2009. Hybrid pigeonpea – the seeds of excellence. Pages 392-407 *in* Legumes for Ecological Sustainability: Proceedings of the National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities (Masood Ali, Sanjeev Gupta, Basu, PS and Naimuddin, eds.). 3-5 November 2007, Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

40.   Saxena KB. 2009. Increasing production of pulses through breeding with special reference to hybrid pigeonpea. Indian merchant's chamber, economic research and training foundation. Pages 45-55 *in* Proceedings of high powered seminar on "Achieving Self–sufficiency in Agriculture Production and Nutrition". NABARD Publication.

41.   Sharma HC and Dhillon MK. 2009. Recent advances in application of biotechnological tools for pest management. Pages 1-12 *in* National Symposium on Biotechnological and Biorational Approaches for Pest Management in Agriculture; and 33rd Annual Conference of Ethological Society of India (Balikai RA, Nanadihalli BS, Krishna Naik L and Biradar DP, eds.). 6-7 November 2009, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India.

42.   Singh NP and BANTILAN MCS. 2009. Climate change resilience in agriculture: vulnerability and adaptation concerns of semi-arid tropics in Asia. Pages 189-236 *in* Proceedings of the Indo-US workshop on Emerging issues in water management for sustainable agriculture in South Asia region, jointly organized by Central Soil and Water Conservation Research and Training Institute, Tamil Nadu, India and Michigan State University, East Lansing, MI, USA, held at CSWCRTI, Ooty, Udagmandalam, 10-12 December, 2009.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

43.   Sreedevi TK, Wani SP and Nageswara Rao V 2009. Empowerment of women for equitable participation in watershed management for improved livelihoods and sustainable development: An analytical study. Pages 1-20 *in* Proceedings of the Workshop on Comprehensive Assessment of Watershed Programs in India, 25 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162.
source: http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

44.   Sreedevi TK, Wani SP, Osman and Shailendra Tiwari. 2009. Rehabilitation of degraded lands in watersheds. Pages 205-220 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162.
source: http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

45.   SREEDEVI TK, Wani SP, **Srinivasa Rao Ch, Raghu Chaliganti** and **Ramalinga Reddy**. 2009. Jatropha and Pongamia rainfed plantations on wastelands in India for improved livelihoods and protecting environment. Pages 102-122 *in* Proceedings of 6th International Biofuels Conference, March 4-5, 2009: Winrock International, New Delhi.

46.   Srinivasa Rao P, **Prakasham RS**, Belum VS Reddy, William D Dar, Wilfred Vermerris, Jeff Pederson and Bruce Dein. 2009. Development of low lignin, high biomass energy sorghums and fermentation protocols for lignocellulosic ethanol production using novel enzyme blend and microbial strains. Pages 54-61 *in* the Proceedings of the workshop on Second Generation Biofuels, 12-13 Oct, Ministry of New and Renewable Energy (MNRE). Government of India. New Delhi.

47.   Tabo R, Bationo A, Hassane O, **Amadou B**, **Fosu M**, Ndjeunga J, Fatondji D, **Korodjouma O,** Abdou A and Koala S. 2009. Fertilizer microdosing for the prosperity of the resource poor farmers: A success story. Pages 269-277 *in* Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor Smallholder Farmers (Humphreys E and Bayot RS, eds.). Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 311 pp. ISBN: 978-92-990053-2-3.

48.   Tabo R, Bationo A, **SAWADOGO-KABORE S**, Hassane O, **Amadou B**, **Siebou P, Ouedraogo S**, Fatondji D*,* **Sigue H,** Koala S, **Fosu M** and FREDAH M. 2009. Institutional innovation: the potential of the warrantage system to underpin the green revolution in Africa. Pages 279-291 *in* Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor Smallholder Farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. (Humphreys E and Bayot RS, eds.) The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 311 pp. ISBN 978-92-990053-2-3.

49.   UMARAO SHARMA A and Rao SB. 2009. Preliminary findings of transgenic approaches to manage cereal cyst nematode in India. Pages 204-207 *in* Cereal cyst nematodes: status, research and outlook (Riley IT, Nicol JM and Dababat AA, eds.). CIMMYT: Ankara, Turkey. ISBN: 978-975-407-285-3 SOURCE: http://cbarc.aes.oregonstate.edu/sites/default/files/Yan_and_Smiley_2009__ICCNI__1.pdf

50.   Upadhyaya HD, **Bisht IS**, Gowda CLL and Pundir RPS. 2009. Establishment of core collections of grain legumes: strategy for effective utilization of genetic resources. Pages 311-331 *in* Legumes for Ecological Sustainability: Proceedings of the National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities (Masood Ali, Sanjeev Gupta, Basu, PS and Naimuddin, eds.). 3-5 November 2007, Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

51.   Upadhyaya HD, Dwivedi SL, Varshney RK, Gowda CLL, *BHATTACHARJEE R*, Hoisington DA, and Vadez V. 2009. Enhancing the value of legume genetic resources using core/mini core and applied genomic tools. Pages 18-25 *in* International Conference on Current Trends in Biotechnology & Implications in Agriculture, Feb, 19-21, 2009 Meerut, India.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

52.	Upadhyaya HD, SHARMA S and Gowda CLL. 2009. Mini core collection: An international public good to enhance use of germplasm in crop improvement. Pages 1-11 *in* National Symposium on Recent Global Development in the Management of Plant Genetic Resources, December 17-18, 2009, NBPGR, New Delhi, India.

53.	Van Rooyen A and Homann Kee Tui S. 2009. Promoting goat markets and technology development in semi-arid Zimbabwe for food security and income growth. Pages 1-5 *in* Tropical and Subtropical Agroecosystems 11(1). Special Issue – Proceedings of the International Goats Conference, held at Mexico, Queretaro, 31 August to 4 September 2008.

54.	VOM BROCKE K and **BARRO C**. 2009. Adaptation and improvement of a broad-based sorghum population with farmers in Burkina Faso. Colloquium on "Mobilizing Regional Diversity for Pearl Millet and Sorghum Intensification in West Africa" held from 5 to 9 May 2009 at Niamey, Niger. Copies available with e(dot)weltzien(at)icrsatml(dot)org or big(dot)haussmann(at)cgiar(dot)org, and on the website http://www.fidafrique.net/IMG/pdf/Adaptation_and_improvement_of_a_broad-based_sorghum_population_with_farmers_in_Burkina_Faso.pdf

55.	Waliyar F, Upadhyaya HD, Ntare BR, Diallo A and Diallo M. 2009. Phenotyping groundnut mini-core collection for resistance to *Aspergillus flavus* and Aflatoxin contamination, Sadore, Niger. Pages 1-16 *in* Fourth International Conference of the Peanut Research Community on *Advances in Arachis through Genomics and Biotechnology* (AAGB-2009) & West and Central Africa Regional Peanut Workshop, 19-22 October 2009, Bamako, Mali.

56.	Wani SP and Kaushal K Garg. 2009. Watershed management concept and principles. Pages 1-11 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

57.	Wani SP, Marimuthu S, Piara Singh, SREEDEVI TK, **Thang NV** and **Banyong Toomsan**. 2009. Increased resource conservation and improved livelihoods through legume-based cropping systems. Pages 29-53 *in* National symposium on Legumes for ecological sustainability: Emerging challenges and opportunities. November 3-5 2007. Indian Society of Pulses Research and Development, IIPR, Kanpur, India.

58.	Wani SP, Pathak P and Sahrawat KL. 2009. Sustainable productivity enhancement initiatives in India. Proceedings of the Tata-ICRISAT-ICAR projects' Review and Planning Meeting. May 2009. International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India: 160 pp. ISBN: 978-92-9066-520-5

59.	Wani SP, Sahrawat KL, SREEDEVI TK, Pardhasaradhi G and Sreenath Dixit 2009. Knowledge-based entry Point for enhancing community participation in integrated watershed management. Pages 53-68 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

60.	Wani SP, SREEDEVI TK, **Joshi PK** and **Venkateswarlu B**. 2009. Development, integration and dissemination of resource conservation options through community watershed approach. 2009. Pages 277-293 *in* 4th World Congress on Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment, 4-7 February, 2009, New Delhi, India.

61.	Wani SP, SREEDEVI TK, Marimuthu S, Kesava Rao AVR and VINEELA C. 2009. Harnessing potential of *Jatropha* and *Pongamia* plantations for improving livelihoods and rehabilitating degraded lands. Pages 256-272 *in* Proceedings of 6th International Biofuels Conference, March 4-5, 2009: Winrock International, New Delhi.

62.	Wani SP, SREEDEVI TK, **Thawilkal Wangkahart** and **Yin Dixin**. 2009. Community watersheds for sustainable development and improved livelihoods in dryland areas of Asia. Volume IV, Pages 1841-1855 *in* Proceedings of the International Conference on Water, Environment, Energy and Society (WEES) 2009. Water Resources and Management.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

63.   Wani SP, Srinivasa Rao Ch, Subba Rao A and Shankar MA. 2009. Integrated nutrient management for sustainable land use in watersheds. Pages 139-153 *in* Proceedings of the Comprehensive Assessment of Watershed Programs in India, 25-27 July 2007. ICRISAT, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN: 978-92-9066-510-6. CPE 162. http://dspace.icrisat.ac.in/dspace/bitstream/123456789/845/1/Proceedings-A%20Comprehensive-Assessment-watershed.pdf

64.   WELTZIEN E and HAUSSMANN BIG. 2009. Learning about recurrent selection of pearl millet and sorghum with options for involving farmers. Colloquium on Mobilizing Regional Diversity for Pearl Millet and Sorghum Intensification in West Africa held from 5 to 9 May 2009 at Niamey, Niger. Copies available with e(dot)weltzien(at)icrsatml(dot)org or b(dot)ig(dot)haussmann(at)cgiar(dot)org.

65.   WELTZIEN E. 2009. Seed system enhancement in collaboration with rural development project and farmers' organizations. 2009. Colloquium on Mobilizing Regional Diversity for Pearl Millet and Sorghum Intensification in West Africa held from 5 to 9 May 2009 at Niamey, Niger. Copies available with e.weltzien@icrsatml.org or b.ig.haussmann@cgiar.org, and on the website http://www.fidafrique.net/IMG/pdf/Seed_System_Enhancement_in_collaboration_with _rural_development_project_and_farmers_organizations-4.pdf

66.   Asfaw S, *MITHOEFER D* and Waibel H. 2008. EU food-safety standards in African high-value crops: Pesticide use and productivity. XIIth Congress of the European Association of Agricultural Economics, August 26-29, 2008, Ghent, Belgium. 9 pp. http://ageconsearch.umn.edu/bitstream/44145/2/222.pdf

67.   Dar WD, Pande S and Keatinge JDH 2008. Food legumes in cropping systems and farmers participatory approaches. Volume 1, Pages 763-786 *in* Food Legumes for National Security and Sustainable Agriculture, Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV) (Kharkwal MC, ed.) held at New Delhi, India, 18-22 October 2005.

68.   Gaur PM, Jagdish Kumar, Gowda CLL, Pande S, Siddique KHM, Khan TN, Warkentin T, **Chaturvedi SK**, Than AM and **Ketema D**. 2008. Breeding chickpea for early phenology: Perspectives, progress and prospects. Volume 2, Pages 39-48 *in* Food Legumes for Nutritional Security and Sustainable Agriculture: Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV) (Kharkwal MC, ed.). 18-22 October 2005, New Delhi, India: Indian Society of Genetics and Plant Breeding, New Delhi, India.

69.   Gowda CLL, Pundir RPS, Upadhyaya HD, Seymour M, **Masood Ali**, Matiur Rahman M, Zong X, Khalil S, Haqqani AM, Sabaghpour SH, Aung May Than and Miligo JK. 2008. Impact of research and development in food legumes on production and productivity in the last two decades. Pages 54-71 *in* Food Legumes for Nutritional Security and Sustainable Agriculture: Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV) (Kharkwal MC, ed.), Volume 1, 18-22 October 2005, New Delhi, India: Indian Society of Genetics and Plant Breeding, New Delhi, India.

70.   Kashiwagi J, Krishnamurthy L, Upadhyaya HD, Chandra S and Gaur PM. 2008. Genetic control of drought avoidance root traits in chickpea (Cicer arietinum L.). Volume 2, Pages 584–588 *in* Food Legumes for Nutritional Security and Sustainable Agriculture,. Indian Society of Genetics and Plant Breeding (Kharkwal MC, ed.). Printed in India. Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV), October 18–22, 2005, New Delhi, India. ISGPB, New Delhi, India.

71.   Mazvimavi K, Twomlow S, Murendo C and Musitini S. 2008. Science in agricultural relief and development programs: The case of conservation farming in Zimbabwe. Pages 321-325 *in* Agricultural Growth, Poverty Reduction and Millennium Development Goals in Africa (Nambiro E, Omare MN, Guy B and Nkamleu GB, eds.) Outcomes of AAAE Conference, August 18– 22, 2007. La Palm Beach Hotel, Accra, Ghana.

72.   Minde IJ and Mazvimavi K. 2008. The Economics of biotechnology (GMOs) and the need for a regional policy: The case for COMESA countries. Pages 377-381 *in* Agricultural Growth, Poverty Reduction and Millennium Development Goals in Africa (Nambiro E, Omare MN and Guy B Nkamleu GB, eds.) Proceedings of AAAE Conference, August 18– 22, 2007. La Palm Beach Hotel, Accra, Ghana. http://ageconsearch.umn.edu/bitstream/52150/2/Minde.pdf

73.   Monika Lulsdorf, Heather Clarke, Nalini Mallikarjuna, Bunyamin Taran and Warkentin T. 2008. Finding solutions for interspecific hybridization problems in chickpea. Volume 2, Pages 12-18 *in* International Food Legume Research Conference IV, MC Kharkwal (ed.). Food Legumes for Nutritional Security and Sustainable Agriculture. Indian Society of Genetics and Plant Breeding.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

74. **Mpandeli S, Simalenga T**, Siambi M, **Ramugondo R, Mailula N** and **LIPHADZI K.** 2008. Constraints and challenges to agricultural development in Limpopo Province, South Africa. Volume 2, Pages 138-143 *in* Fighting Poverty through Sustainable Water Use (Humphreys E, Bayot RS, van Brakel M, Gichuki F, Svendsen M, Wester P, Huber-Lee A, Cook S, Douthwaite B, Hoanh CT, Johnson N, Nguyen-Okhoa S, Vidal A, MacIntyre I and MacIntyre R, eds.). Proceedings of the CGIAR Challenge Program on Water and Food, 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, November 10-14, 2008. The Challenge Program on Water and Food, Colombo. 217pp. ISBN: 978-92-990053-2-3.

75. Nalini Mallikarjuna, Kulbhushan Saxena, David Hoisington, Fred Muehlbauer, Heather Clarke and Clarice Coyne. 2008. Unlocking genetic potential of wild species for legume crop improvement. Volume 2, Pages 24–28 *in* International Food Legume Research Conference IV, MC Kharkwal (ed.). Food Legumes for Nutritional Security and Sustainable Agriculture. Indian Society of Genetics and Plant Breeding.

76. Pande S, **SHARMA M** and Narayana Rao J 2008. Etiology, biology and management of diseases of food legumes. Volume 2, Pages 363-377 *in* Food Legumes for National Security and Sustainable Agriculture, Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV) (Kharkwal MC, ed.) held at New Delhi, India, 18-22 October 2005.

77. Saxena KB, Kumar RV, Dalvi VA, Nalini Mallikarjuna, Gowda CLL, **Singh BB**, **Tikka SBS**, **Wanjari KB**, **Pandey LB**, **Paralkar RM**, **Patel MK**, Bao Shiying and Zong Xuxiao. 2008. Hybrid breeding in grain legumes: A success story of Pigeonpea. Volume 1, Pages 166-173 *in* Food Legumes for Nutritional Security and Sustainable Agriculture: Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV) (Kharkwal MC, ed.). 18-22 October 2005, New Delhi, India: Indian Society of Genetics and Plant Breeding, New Delhi, India.

78. Shahal Abbo and Nalini Mallikarjuna. 2008. Distant hybridisation in food legumes. Volume 1, Pages 174–179 *in* International Food Legume Research Conference IV, MC Kharkwal (ed.). Food Legumes for Nutritional Security and Sustainable Agriculture. Indian Society of Genetics and Plant Breeding.

79. SIMPUNGWE JJ, PEDZISA T, **Masenya M** and Minde I. 2008. Marketing small packs of fertilizer in Limpopo Province, South Africa. *In* Fighting poverty through sustainable water use (Humphreys E, Bayot RS, van Brakel N, Gichuki F, Svendsen M, Wester P, Huber-Lee A, Cook S, Douthwaite B, Hoanh CT, Johnson N, Nguyen-Khoa S, Vidal A, MacIntyre I and Macintyre R, eds). Proceedings of the CGIAR Challenge Program on Water and Food—2nd International Forum on Water and Food, Addis Ababa, Ethiopia, November 10-14 2008, (Volume II). CGIAR Challenge Program on Water for Food, Colombo, Sri Lanka. Available at http://ifwf2.org/
ISBN: 978-92-990053-2-3.

80. Upadhyaya HD and Gowda CLL. 2008. Use of core collection approach to enhance germplasm utilization in chickpea and pigeonpea. Volume 2, Pages 591–598 *in* Food Legumes for Nutritional Security and Sustainable Agriculture, Indian Society of Genetics and Plant Breeding (Kharkwal MC, ed.). Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV), October 18–22, 2005, New Delhi, India. ISGPB, New Delhi, India.

81. Vander Maesen LJG, Pundir RPS and Upadhyaya HD. 2008. Use made of wild relatives in breeding. Volume 2, Pages 741–749 *in* Food Legumes for Nutritional Security and Sustainable Agriculture (Kharkwal MC, ed.). Indian Society of Genetics and Plant Breeding. Printed in India. Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV), October 18–22, 2005, New Delhi, India. ISGPB, New Delhi, India.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

Monographs

1.   Anand Babu P and BANTILAN MCS. 2009. Addressing climate change vulnerability through adaptation: Learning lessons from risk to resilience in the dryland agriculture. Invited paper for Compendium of Training Course on "Effect of Climate Change on Water Productivity: Coping Strategies and Management", Central Research Institute for the Dryland Agriculture (CRIDA), Hyderabad. 7 pp.

2.   Chilonda P, Olubode-Awusola F and Minde I. 2009. Monitoring public spending in agriculture in Southern Africa. ReSAKSS-SA Issue Brief 08. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI). 8pp (www.sa.resakss.org)

3.   Mazvimavi K, Dimes J and Ndlovu P. 2009. Trends in adoption of conservation farming practices among smallholder farmers in Zimbabwe. FAO and GRM/MTLC, Harare. 54pp.

4.   Mazvimavi K. 2009. Adoption of conservation farming practice in small holder farming areas of Zimbabwe: Interim results from 2008/09 Panel Study. FAO, Harare. 9pp.

5.   Tschirley D, Minde I and Boughton, D. 2009. Contract farming in Sub-Saharan Africa: Lessons from cotton on what works under what conditions. ReSAKSS-SA Issue Brief 07. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI). 11pp. (www.sa.resakss.org)

6.   Twomlow S, Hove L, Mupangwa W, MASIKATI P and **MASHINGAIDZE N**. 2009. Precision conservation agriculture for vulnerable farmers in low-potential zones.   Pages 37-54 *in* Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers (Humphreys E and Bayot RS, eds.)*.* Proceedings of the CGIAR Challenge. Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22–25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. ISBN: 978-92-990053-4-7.

7.   *VAN DE STEEG J, Hererro M, Kinyagi J, Thornton PK, Rao KPC,* Stern R andCooper P. 2009. The influence of climate variability and climate change on the agricultural sector in East and central Africa – Sensitizing the ASARECA strategic plan to climate change. Research Report 22, ILRI. 85pp. ISBN 92-9146-238-1. ISBN: 92-9146-238-1.

8.   Nageswara Rao GD, Anand Babu P and BANTILAN MCS. 2009. Dynamics and development pathways in the semi-arid tropics: Dokur village profile. Research Bulletin 23. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp. ISBN: 978-92-9066-516-8.

9.   Osman Mohammed, Wani SP, VINEELA C and Murali R. 2009. Quantification of Nutrients recycled by tank silt and its impact on soil and crop - A pilot study in Warangal District of Andhra Pradesh. Global Theme on Agroecosystems Report no. 52. Patancheru 502 324, Andhra Pradesh, India; International Crops Research Institute for Semi-Arid Tropics. 20 pp.

10.   **Palanisami K**, **Suresh Kumar D** and Wani SP. 2009. A Manual on impact assessment of watersheds. Global Theme on Agroecosystems Report no. 53. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi- Arid Tropics. 56 pp.

11.   Srinivasa Rao P, Rao SS, Seetharama N, Umakanth AV, Sanjana Reddy P, Reddy BVS and Gowda CLL. 2009. Sweet sorghum for biofuel and strategies for its improvement . Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp. ISBN: 978-92-9066-518-2.

12.   Upadhyaya HD and Laxmipathi Gowda CL. 2009. Managing and enhancing the use of germplasm – Strategies and methodologies. Technical Manual no.10. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi Arid Tropics. 236 pp. ISBN: 978-92-9066-514-4.

Bold=**NARES**; Underline=ARI; Italics=*CG Center Scientist*; ALL CAPS=FEMALE SCIENTIST

362

13. Upadhyaya HD, Pundir RPS, Dwivedi SL and Gowda CLL. 2009. Mini core collections for efficient utilization of plant genetic resources in crop improvement programs. Information Bulletin No.78. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi Arid Tropics. 52 pp. ISBN: 978-92-9066-519-9.

14. Wani SP, SREEDEVI TK, **Sreenath Dixit, Kareemullah K**, **Ravindra Singh** and **Tirupathaiah K**. 2009. Consortium approach for capacity building for watershed management in Andhra Pradesh: A Case Study. Global Theme on Agroecosystems Report no. 51. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi- Arid Tropics. 48 pp.

15. Minde I, Chilonda P and Sally H. 2008. Rising global food prices: Policy challenges and options for Southern Africa. 2008. ReSAKSS SA Issue Brief No 6. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI) 6 pp, (www.sa.resakss.org).

16. Olubode-Awosola O, Chilonda P, Minde I and Bhatt, Y. 2008. Indicators for monitoring and evaluation of agriculture performance and shared goals in Southern Africa. ReSAKSS-SA Working Paper 24. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI). 41pp (www.sa.resakss.org).

17. Upadhyaya HD, Reddy KN and Sastry DVSSR. 2008. Regeneration guidelines: pigeonpea. Crop specific regeneration guidelines [CD-ROM] (Dulloo ME, Thormann I, Jorge MA and Hanson J, eds.). CGIAR System-wide Genetic Resources Program, Rome, Italy. 8 pp.

18. Upadhyaya HD, Reddy KN and Sastry DVSSR. 2008. Regeneration guidelines: pearl millet. Crop specific regeneration guidelines [CD-ROM] (Dulloo ME, Thormann I, Jorge MA and Hanson J, eds.). CGIAR System-wide Genetic Resources Program, Rome, Italy. 9 pp.

19. Upadhyaya HD, Reddy VG and Sastry DVSSR. 2008. Regeneration guidelines: sorghum. Crop Specific regeneration guidelines [CD-ROM] (Dulloo ME, Thormann I, Jorge MA and Hanson J, eds.). CGIAR System-wide Genetic Resources Program, Rome, Italy. 8 pp.

20. Upadhyaya HD, Reddy VG and Sastry DVSSR. 2008. Regeneration guidelines: finger millet. Crop Specific regeneration guidelines [CD-ROM] (Dulloo ME, Thormann I, Jorge MA and Hanson J, eds.), CGIAR System-wide Genetic Resources Program, Rome, Italy. 7 pp.

International Newsletters

1. Sharma HC, Dhillon MK, **Bhagwat VR** and Reddy BVS. 2009. Insect pests of sorghum and their management. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 12 pp.

2. Sharma KK and BHATNAGAR-MATHUR P. 2009. Transgenic improvement of pigeonpea and chickpea at ICRISAT. South Asia Biotech Program Newsletter 5(2):1-2.

3. Sharma KK, BHATNAGAR-MATHUR P and **Rao SR.** 2009. Platform for translational research on transgenic crops: crossing over. Biotech News, Department of Biotechnology, Ministry of Science and Technology, Government of India. 4(2):34-36.

4. Srinivasa Rao P, Reddy BVS, Thakur RP, Sharma HC, *Blummel M*, SANJANA REDDY P, Ashok Kumar A, Ravinder Reddy Ch, Parthasarathy Rao P and Gowda CLL. 2009. Sweet sorghum as a multipurpose biofuel crop: ICRISAT's efforts in cultivar development and commercialization. APAARI Newsletter 18(2).

5. Asfaw S, *MITHOEFER D* and Waibel H. 2008. Food-safety Standards: A Catalyst for the Winners - a Barrier for the Losers? The Case of GlobalGAP in Horticultural Export from Kenya. Fresh Perspective Series 18:2. http://www.agrifoodstandards.net/en/filemanager/active?fid=120

6. **Kumar J, Saharan MS, Sharma AK**, Ganga Rao NVPR, **SUSHILA KUNDU**, **Jag Shoran** and **Sudhir Sharma**.2008.Evaluation of synthetic hexaploid and indigenous wheat lines for resistance to Karnal bunt. Annual Wheat News letter 54:66-67.

7. Nikiema A. 2008. Karité (*Vitellaria paradoxa*): a high value vegetable oil crop from the semi arid tropics of Africa. PROTA Newsletter 7: page 7.

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ICRISAT

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The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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