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INTSORMIL Annual Report 1994

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EXECUTIVE SUMMARY

INTSORMIL

Annual Report 1994

SORGHUM/MILLET COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

Fighting Hunger with Research ... a team effort

Funding support through the Agency for International Development

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Cover Photographs
(top to bottom)

1. Aboubacar Touré with panicle of new advanced generation white seeded, tan plant, Guinea type breeding line. Sotuba, Mali - October, 1994. Photo courtesy of Dr. Darrell Rosenow.

2. A Nicaraguan worker selecting broomcorn fiber by different sizes. Photo courtesy of Dr. Franciso Gomez.

3. John Yohe, INTSORMIL Program Director, on the left and Phillip Warren, USAID INTSORMIL Project Officer, on the right, reviewing the sorghum nursery at Purdue University. Photo courtesy of Phillip Warren.

4. Quarantine growout and increase of Sudan sorghum collection (approximately 3,100 sorghum cultivars) in St. Croix, U.S Virgin Islands - January 1994. Photo courtesy of Dr. Darrell Rosenow.

INTSORMIL

Annual Report 1994

Fighting Hunger with Research . . . A Team Effort

Executive Summary

Grain Sorghum/Pearl Millet Collaborative Research Support Program (CRSP)

The Sorghum/Millet Collaborative Research Support Program (CRSP) is an initiative of the Agency for International Development, Grant No. DAN-1254-G-00-0021-00, Title XII and the Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC), the participating U.S. Universities and other collaborating institutions.

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A Research Development Program of the Agency for International Development, the Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC), Participating Land-Grant Universities, Host Country Research Agencies and Private Donors

INTSORMIL INSTITUTIONS

Kansas State University
Mississippi State University
University of Nebraska
Purdue University
Texas A&M University

INTSORMIL Institutions are affirmative action/equal opportunity institutions.

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Introduction and Program Overview

The INTSORMIL program, initiated in 1979, is one of ten Collaborative Research Support Programs (CRSPs) established through USAID core funding to respond to the Title XII legislation mandate to "... improve the participation of these (the agriculturally related) universities in the United States' governmental efforts internationally to apply agricultural sciences more effectively to increasing world food production and provide... support to the application of science to solving developing countries' food and nutrition problems". The INTSORMIL program was designed to respond to the intent of the Title XII legislation by focusing on grain sorghum and pearl millet related issues in strategically selected regions of the world.

Sorghum and millet are important world food crops in moisture stressed regions of the world. They are staple foods for millions in Africa and Asia which, in their area of adaptation, cannot be substituted by other cereals. Sorghum is also a major feed grain in the U.S. and Mexico and in other countries in South America.

In working with selected host countries where sorghum and millet are important crops, INTSORMIL is now capitalizing upon the institutional and technical expertise of five land-grant universities to focus on the special constraints of sorghum and millet production, processing, utilization, and marketing in the collaborating host countries. The universities which are still active in the INTSORMIL CRSP are Kansas State University, Mississippi State University, University of Nebraska, Purdue University, and Texas A&M University. The prime sites actively collaborating with INTSORMIL are Botswana, Colombia, Honduras, Mali, Niger and Sudan. Several other countries such as Senegal, Burkina Faso, Egypt, Kenya, Zimbabwe and El Salvador are also collaborating at a lower level.

The primary approach for INTSORMIL to reach its goal is to foster and cultivate the collaborative research mode involving the partnership of U.S. and host country scientists. They develop and transfer appropriate scientific technologies and strategies for alleviating the dominant sorghum and millet production and utilization constraints of the participating host countries and the U.S. Building and strengthening the manpower and the institutional capacities of the host countries for implementing effective collaborative research programs continues to be an important and necessary part of the INTSORMIL CRSP. INTSORMIL is committed to increasing production while maintaining and enhancing the natural resource base of sorghum and millet production both in the host countries and the U.S.

INTSORMIL currently provides technical backstopping, conducts collaborative research, trains national staff and students, and contributes operational support to National Agricultural Research Systems (NARS) grain sorghum and pearl millet programs. The success of INTSORMIL can be attributed to five unique features.

- INTSORMIL capitalizes on over 90% of U.S. Universities grain sorghum and pearl millet research capacity where most basic and strategic research is conducted. This allows the unique opportunity to support and complement applied field work conducted at NARS sites by adding an otherwise unknown dimension to the research.

- INTSORMIL is an integrated, interdisciplinary organization encompassing breeding, agronomy, physiology, insect and disease management, food quality, and economics.

- INTSORMIL enhances the capacity of NARS to solve country and region-specific problems through collaborative research, thus increasing NARS technical and institutional productivity.

- INTSORMIL activities are constraint and NARS driven: identification and alleviation of priority production constraints are achieved in concert with NARS.

- The INTSORMIL strategy focuses on five technical thrusts, each aimed at increasing productivity and improving sustainability:

  * Germplasm Enhancement—the development of resource efficient cultivars.

  * Sustainable Production Systems—the establishment of environmentally safe and financially profitable production systems.

  * Sustainable Plant Protection Systems—the development of environmentally sound and economical pest control systems.

  * Crop Utilization and Marketing—the development of shelf stable processed foods with good marketing potential as well as improving traditional food processing systems.

  * National Sorghum and Millet Research Program Enhancement—short and long term training for NARS staff, equipment procurement, and overall NARS operations support.

Administration and Management

The University of Nebraska (UNL) is the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of USAID. UNL subgrants are made to the participating U.S. Universities for the research projects between individual U.S. scientists and their host country counterparts. Country project funds, managed by the ME and U.S. participating institutions, flow to the country program in support of the research activities at the host country level. The Board of Directors (BOD) of the CRSP serves as the top management/policy body for the CRSP. The Technical Committee (TC), Ecogeographic Zone Council (EZC), External Evaluation Panel (EEP) and USAID personnel advise and guide the ME and the Board in areas of policy, technical aspects, collaborating host country coordination, budget management, and review.

Several major decisions and accomplishments were made by the ME, BOD, TC and EZC during the past year.

- Draft No. 3 of the INTSORMIL Ten Year Strategic Plan has been prepared. Two other documents for the Strategic Plan were prepared. Those are:
  - Reports on Domestic Sites covering all current INTSORMIL domestic institutions.
  - Country Status Reports covering all the countries where INTSORMIL is operating.
- The INTSORMIL External Evaluation Panel (EEP) completed its five year review of the host country sites in October, 1993. During the period of July 1, 1993 to June 30, 1994 the EEP completed the review of all domestic research sites (Texas A&M, Mississippi State, Nebraska, Kansas State and Purdue Universities). The panel's Five Year Report was released in March, 1994.
- INTSORMIL served as joint sponsor and organizer of the workshop, "Adaptation of Plants to Soil Stress" which was held August 1-4, 1993 at the University of Nebraska. Sixty-seven invited participants representing eleven countries were present for the meeting.
- The major publications organized and published by the ME office during the year included:
  - INTSORMIL Newsletter, INTSORMIL Publication No. 94-1.
  - Proceedings of the Workshop on Adaptation of Plants to Soil Stresses, August 1-4, 1993, INTSORMIL Publication No. 94-2.
  - INTSORMIL Newsletter, INTSORMIL Publication No. 94-3.
  - INTSORMIL Annual Report 1993, INTSORMIL Publication No. 94-4.
  - INTSORMIL Annual Report 1993, Executive Summary, INTSORMIL
  - INTSORMIL Bibliography, 1984-1994, INTSORMIL Publication No. 94-5.
  - The research bulletin entitled "New Approaches to the Control of *Striga*" written by scientists at Purdue University and collaborating Sudanese scientists was published by the Purdue University Experiment Station.
- The INTSORMIL Host Country Coordinators from Mali, Niger, Sudan and Botswana elected Dr. Ouendeba Botorou of Niger as the first Host Country representative to the Ecogeographic Zone Council.
- Dr. Francisco Gomez, Esquela Panamericana, San Zamorano, Honduras was elected as the first Host Country representative to the Technical Committee.
- The INTSORMIL BOD approved the 1994-95 annual budget which included a 11.1% reduction in funds.
- INTSORMIL opened a worldwide search for the position of Associate Director. This search was later canceled due to the budget reduction.
- INTSORMIL plant pathologists, Dr. John F. Leslie, Kansas State University and Dr. R.A. Frederiksen, Texas A&M University, were responsible for organizing a conference on "Application of Genetics and Biotechnology to the Characterization and Control of Fungal Pathogens: An International Sorghum and Millet Perspective". The conference was held at the Rockefeller Foundation Center, Bellagio, Italy, November 15-19, 1994. A broad range of topics in the general area of molecular biology, genetic maps and diversity, plant disease control, mating populations, and pathotype diversity of fungal pathogens of sorghum and millet were covered. The proceedings of this conference are to be published in early 1995.
- The International Consultative Workshop on Panicle Insect Pests of Sorghum and Pearl Millet was jointly organized and sponsored by ICRISAT and INTSORMIL. It was held October 4-7, 1993, at the ICRISAT Sahelian Center, Niamey, Niger.
- Based upon a request from the Institute of Agricultural Research (IAR) of Ethiopia, INTSORMIL provided short-term (3-6 months) training for six Ethiopian scientists at three INTSORMIL Universities. Each of these Ethiopians holds an M.S. degree and had over five years of work experience in research. This special training focused on different disciplines of sorghum

research and was sponsored by the IAR through World Bank funding.

- INTSORMIL's three year grant under the Egyptian National Agricultural Research Program (NARP) entitled "Sorghum/Millet Collaborative Research" ended on June 30, 1994. Components of the grant were "Water Use Efficiency in Sorghum Based Cropping Systems" in collaboration with Dr. Jerry Eastin at the University of Nebraska, and "Stalk and Root Rot Complexes and Associated Diseases of Sorghum in Egypt" in collaboration with Drs. Larry Claflin and John Leslie at Kansas State University. "Pokkah boeng" was identified as a serious disease problem on one of the most popular Egyptian cultivars, Giza 15, and has become a new area of research that is continuing even though this project has formally lapsed.

CRSP Review Team

USAID conducted an overall evaluation of the Collaborative Research Support Programs (CRSPs), including INTSORMIL, between May and July 1994. According to the "CRSP Evaluation Scope of Work" developed by USAID, the goal of this evaluation was to provide an objective assessment of the degree to which each of the CRSPs has had an impact on increasing agricultural production and development, and improving natural resource management through the development and dissemination of new and/or more appropriate sustainable agriculture technologies. The evaluation also assessed the extent to which the CRSP framework has responded to past Agency expectations and objectives and if the CRSP model can be used to respond to future Agency needs and requirements.

The members of the evaluation team were: Dr. Les Swindale, Team Leader and Institutional Management Specialist; Dr. John Ericksen, Agricultural Economist; Dr. Charlotte Miller, Rural Sociologist; Dr. George Marlowe, Plant Scientist; Dr. Rattan Lal, Soil Scientist; Dr. Richard Gray, Animal Scientist; Dr. Gary Jensen, Aquaculture Specialist; and Dr. Izadore Barrett, Fisheries Specialist.

The team visited both domestic and host country sites where the CRSPs are operating. The domestic INTSORMIL institutions visited were the University of Nebraska, Purdue University and Texas A&M University. The host country sites which were visited, with the objective of evaluating past and/or present INTSORMIL related collaborative programs, were Mali, Niger, Kenya, Honduras and Brazil. In addition to INTSORMIL, six other CRSPs were being evaluated by the team.

Training

Training of host country scientists contributes to the capability of each host country research program to stay abreast of environmental and ecological changes which alter the balance of sustainable production systems. The strengthening of host country research institutions contributes to their capability to predict and be prepared to combat environmental and ecological changes which affect sorghum and millet. A well balanced institution will have to be prepared to prioritize and blend its operational efforts to accomplish the task of conserving and efficiently utilizing its natural resources.

During 1993-94, 96 students from 33 different countries were enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. Seventy-eight percent of these students came from countries other than the U.S. which illustrates the emphasis placed on host country institutional development. INTSORMIL also places importance on training women which is reflected in the fact that 20% of all INTSORMIL graduate students were women.

The number of students receiving 100% funding by INTSORMIL in 1993-94 totaled 17. An additional 29 students received partial funding from INTSORMIL. The remaining 50 students were funded from other sources but are working on INTSORMIL projects. Total student numbers increased by six as compared to 1992-93. The number of students receiving 100% funding from INTSORMIL has dropped from a high of 71 in 1986 down to a low of 17 in 1993-94. This is, in part, due to training taking place under other funding sources, but an even more significant factor is that budget flexibility for supporting training under INTSORMIL projects has been greatly diminished because of reductions in our overall program budget and because of inflationary pressures.

In addition to graduate degree programs, short term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Several host country scientists were provided the opportunity to upgrade their skills in this fashion during 1993-94.

INTSORMIL cooperated with ICRISAT on a ten year special training program for countries of the Southern Africa Development Community which terminated in 1993. The SADC/ICRISAT Regional Sorghum and Millet Research Program was designed to respond to the need of the 10 member states of SADC, to initiate research on sorghum and millets in the marginal rainfall areas of the region. The program was implemented by ICRISAT and funded by USAID, CIDA and GTZ. The total number of active SADC students was 40 for 1993-94.

Networking

Over the years, established networking activities have continued with ICRISAT, SADC/ICRISAT, SAFGRAD, ICRISAT Sahelian Center, ICRISAT West Africa Sorghum Improvement Program, EARSAM of ICRISAT, ICRISAT/CIMMYT, CLAIS of Central and South America, and CIAT. There has been excellent collaboration with each of these programs in co-sponsoring workshops and conferences, and for coordination of research and long term training. INTSORMIL is working with newly emerging networks, such as ROCAFREMI (Réseau Ouest et Centre Africain de Recherche sur le Mil, Niger) of West/Central Africa. INTSORMIL plans to strengthen linkages among the NARS it works with, as well as international and regional organizations and networks. INTSORMIL will continue to promote free exchange of germplasm, technical information, improved technology, and research techniques.

INTSORMIL/Mali

The research accomplishments in Mali are immediately and directly transferable to most countries in West Africa. Work on sorghum and millet food technology applies to Africa and many areas of the world. Head bugs and drought are common to West Africa. Grain mold is a world-wide problem. Exchange of elite germplasm with useful traits is an excellent means of networking among breeders. Effort is being made to utilize existing networks to extend technology to the region in both sorghum and millet. There has been a long history of collaboration with ICRISAT in Mali, and collaboration with ICRISAT continues to be useful in networking in the areas of entomology, pathology, and breeding.

Within Mali, there is a pre-extension organization to do on-farm trials, followed by extension personnel doing detailed evaluation and demonstration of new technologies. Minamba Bagayoko coordinates extension on-farm trials in the Mopti region. Future plans call for linkages and networking with the NGOs and PVOs working in Mali.

INTSORMIL/Niger

INRAN is the responsible organization for agriculture in Niger. INRAN, as a national Institute, collaborates with other national institutes in sharing germplasm and research results. These include IN.E.R.A. in Burkina Faso, IER in Mali and ARC in Sudan. Increasing collaboration with the ICRISAT Sahelian Center in Niamey will expedite transfer of research results across the Sahelian zone.

A Sorghum Quality Laboratory Manual was developed in collaboration with the Cereal Technology Laboratory in Niger and the Food Technology Unit in Mali. This manual has been widely distributed throughout West African countries.

INTSORMIL/Sudan

The Agricultural Research Corporation of Sudan, INTSORMIL's sole collaborator in Sudan, has an effective network for dissemination of research results to clientele groups. The many agricultural production schemes in Sudan are managed by well-trained agriculturists who interact with ARC scientists in both organized and informal forums. Annual agricultural meetings are held where current research results are presented and emerging constraints are discussed. Both agricultural research and extension scientists from the Ministry of Agriculture attend these annual meetings. Sudanese scientists are active participants in regional and international workshops where contemporary agricultural issues are discussed. Many Sudanese scientists hold leadership positions in regional networking activities. For instance, Dr. A.G.T. Babiker has been the leader of the Pan African *Striga* Control Network and attended meetings in Zimbabwe and Kenya in 1993.

INTSORMIL/Botswana and Southern Africa

Participation of the host country and INTSORMIL scientists in the SADC/ICRISAT Sorghum and Pearl Millet Research Network is increasing.

Electronic mail linkage between national research institutions and universities (both host country and U.S.) is almost a reality. A sorghum/pearl millet bulletin board on Internet would be an excellent vehicle for networking among Southern Africa scientists.

INTSORMIL/Honduras

INTSORMIL's long-term relationship with the MNR has enabled Honduras to develop a long term comprehensive sorghum research program that is beginning to gain support from the sorghum industry in Honduras and other international donors. Special projects are being developed to create new funding sources. To date, these projects have focused on commercial hybrid testing and the international sorghum downy mildew nursery in Comayagua. The national sorghum program won two strengthening grants ($15,000 each) from the EEC this year for the control of sorghum downy mildew in Honduras and support to maicillo breeding activities.

In 1994, Dr. Francisco Gomez was appointed Vice-president of the National Council of PRIAG (Regional Program to Strengthen Agronomic Research on Basic Grains in Central America) which is sponsored by the European Economic Community and administered by IICA. As a senior scientist in the region, he is providing valuable advice to PRIAG in establishing their research grant program. This position adds an important new facet to networking.

Dr. Gómez acts as the liaison officer between the American Society of Agronomy (ASA) and PCCMCA. Dr. Gomez attended the 1994 ASA meetings where he investigated possibilities for opening an ASA Chapter at EAP.

Dr. Fred Miller, INTSORMIL/Texas A&M University sent 4 female and 53 male lines for hybrid seed production in Comayagua. Seed from two improved maiciollos was distributed among 62 farmers in southern Honduras. Seed of six enhanced maiciollos and maicillo criollo was sent to Dr. Page Morgan, Texas A&M University to initiate a study in photosensitivity control. Seed of five broomcorn varieties was sent to Eng. Adolfo Montiel for adaptation studies in Nicaragua.

INTSORMIL/Colombia

This Prime Site was informally linked with many countries in South and Central America and in Africa where CIAT conducts research. Over the years, cooperative research linkages were established with the national research programs of ICA-Colombia, EMBRAPA-Brazil, CENIAP-FONAIAP-Venezuela, INIPA-Peru, and IDIAP-Panama. These countries are in the major acid soil areas and are conducting research to solve soil acidity problems. This collaborative linkage network unified INTSORMIL researchers and host country scientists to solve a common problem in the region through exchange of germplasm, research result dissemination, technical consultation, training, and workshops.

The INTSORMIL Colombian Program, headquartered at CIAT, promoted and established a Latin American network. International workshops held in Colombia were developed and coordinated by INTSORMIL PIs in 1984, 1991, 1992, and 1993. Involving both public and private sectors at national and international levels, the network emphasized the introduction, exchange, storage, increase, and distribution of germplasm. The network planned to maintain samples of the most advanced sources of genetic resistance and variability available in advanced research institutions around the world for those Latin American research institutions which work on sorghum and pearl millet.

Current Country Specific Activites

Mali

The program in Mali is a coordinated effort between INTSORMIL and IER. It is multidisciplinary and multi-institutional in scope and includes all aspects of sorghum and millet improvement, production, and utilization. Each Malian scientist develops research plans cooperatively with an INTSORMIL counterpart in concert with the overall IER Mali research plan. Major INTSORMIL collaborators travel to Mali annually during the critical period of the crop year to consult, review progress, and plan future collaborative activities with their Malian counterparts. Occasionally, IER scientists travel to the U.S. for annual review and planning. These plans are reviewed by the country coordinators, consolidated, and then presented to the IER for their annual research planning process for approval or modification. This insures that the research fits into the annual overall IER plan.

Production and Utilization Constraints

Yield level and stability in sorghum/millet production is of major importance in Mali where food production is marginal relative to the needs of the rapidly growing population. Low and unstable yields are the result of complex interactions of low soil fertility (particularly nitrogen and phosphorus), drought stress, diseases, insect infestations, *Striga*, and availability of improved cultivars.

Head bugs and associated grain molds adversely affect sorghum yield and grain quality, and are a major constraint to the development of improved high yielding sorghum cultivars. *Striga* is a major constraint for both sorghum and millet. Other major millet constraints are phosphorus and nitrogen deficiency, water stress, and millet head miner infestations.

Grain prices which cycle between high and low yield-level years are a deterrent to adoption of improved technology, thus milling properties become critical for maintaining prices in surplus grain production years. Transformation of sorghum and millet grain into new shelf-stable foods and industrial products is required to encourage local production of grains and to enhance agribusiness activities of food processing and poultry feeding which stabilizes prices.

Efforts are concentrated to strengthen research on breeding, crop physiology, soil and water relationships, entomology, pathology, *Striga*, food processing, and food technology. An effort to develop new food products from cereals and legumes is emphasized. Selection for enhanced drought resistance is a major concern. Major activities involve the introduction and use of new genetic materials in breeding programs to develop cultivars to increase or stabilize grain yields with desirable food quality.

Research Progress

Pearl Millet Breeding

The pearl millet breeding program in Mali is making good progress in addressing needed improvements regarding disease and insect resistance, adaptation, and agronomic characteristics that affect productivity. Landraces from different ecological zones have been evaluated at different locations. These materials were collected at Nioro, Bema, Mopti (northeast), and Sikasso (south). Ten high performing ecotypes were selected. They are being improved via the mass selection method. The same entries are being used in a crossing block for their grain quality (kernel size and color).

Many experimental varieties have been evaluated in the CIVAREX, "Cinzana Varieties Experimentales". Several performed well and will be suitable for intercropping with legumes such as cowpea and peanut, and root crops like cassava and sweet potatoes. Several composites were evaluated in isolated plots for dwarfness, head compactness, and downy mildew resistance. Roguing and recombination gave good results.

Several lines derived from nine Malian varieties were screened at Hays, Kansas. Three good lines were retained in Mali. Also, crosses were made between Kansas elite lines and materials from Mali. Fifty-two F_1 and forty-eight F_2

selections were evaluated. They had an acceptable level of downy mildew resistance. Backcrosses will be made with most of these lines. They had suitable height for intercropping. More than sixty entries were evaluated through ICRISAT and ROCAFREMI (Millet Improvement Network in Central and West Africa) collaborative programs. Two or three years evaluation will allow selection of some entries for on-farm evaluation.

Sorghum Breeding
Crossing and Breeding Nurseries

In the 1993 rainy season, 48 parents were planted at Sotuba with 115 new crosses made. These F_1s were planted at Sotuba during the 93-94 off-season to produce F_2s. The best tan-plant Guinea F_6 derivatives were selected to be backcrossed to CSM 388, Bimbiri Soumale and Tiemarifing, in order to enhance the guinea traits to develop very true tan-plant guinea lines.

F_2, F_3, and F_4 progeny were grown at Sotuba, Samanko, Bema, Cinzana, and Longorola with 350 F_2 selections, and 255 F_3 selections made. Eighty-one F_4 families were selected for advance in the off-season to the Preliminary Trial in 1991.

Excellent progress was made in the objective to develop white-seeded, tan-plant guinea cultivars. F_6 progenies from crosses involving Bimbiri Soumale and CSM388 looked very promising. Especially outstanding were the derivatives of the cross, Bimbiri Soumale *87CZ-Zera Zera. They appear to have excellent yield potential. They have good guinea plant, grain, glume, and panicle characteristics, and some have juicy stems. Most Bimbiri Soumale derivatives were F_6s in the preliminary trials, while the best CSM388 derivatives were in the F_4 stage. They will move to the Advanced Trials and Preliminary Trials in 1994.

The progenies from late maturing improved maicillo varieties from the INTSORMIL program in Honduras were not acceptable for grain quality, but had proper maturity for southern Mali. They were recrossed to local and improved types in an attempt to improve the head bug and grain mold resistance.

Advanced Varieties

Three different Preliminary Yield Trials and three Advanced Yield Trials (to fit rainfall belts) were planted and evaluated at Bema, Cinzana, Massantola, Katibougou, Sotuba, Samanko, and Soukoula. From the Advanced Trials, eight were selected for on-farm testing. From the Preliminary Trials, entries were selected to be promoted to the Advanced Trial next year.

In southern Mali, seven cultivars selected from the CMDT southern Mali collection of late, photosensitive sorghums were evaluated at Longorola, Soukoula, and Tierouala. After two years of evaluation, three were selected for on-farm testing and for crosses, Kalagua Seguetana, Foulatieba, and Kalofolo.

Plant Protection

Entomology

Research activities for 1993 were focused essentially on the bio-ecology of head bug (*Eurystylus marginatus*) and the identification of new resistance sources. The fluctuation of larva and adult populations was studied. The population of head bugs was higher in 1993 than in 1992.

In preliminary screening in the field nursery at Sotuba, 49 new advanced generation lines were evaluated under natural infestation conditions. In another three year experiment screening for resistance, we evaluated 50 advanced breeding lines. In the first experiment the entries showing good head bug resistance were 89-CZ-CS-F_5-73 AF, ACSV 401, 88-BE-F_4-257-3, 87-SB-F_4-275-2 and 87-SB-LO-F_4-155 with a visual rating between 1.0 and 1.7. Results in the second experiment showed that the INTSORMIL lines from Texas 90-CZ-CS-TX-2, 90-CZ-CS-TX-12, 90-CZ-CS-TX-6, 90-CZ-CS-TX-1, PR2566 and PR2562 were resistant to head bug under severe natural infestation. All are derivatives of Malisor 84-7. In another advanced screening trial, IS21468 was confirmed as having resistance equal to that of Malisor 84-7.

Diazinon again looked promising in controlling head bugs in 1993. In lines treated with diazinon, the head bug incidence under natural infestation was very low compared to the check. Also, 200 grain-weight was higher for treated heads (4.21g) than for the control under natural infestation (3.20g).

Pathology

Forty lines from INTSORMIL in the GWT (Grain Weathering Test) were screened for grain mold resistance at Sotuba under natural conditions. Six lines, SC170-6-17, SC279-14E, R6078, 87BH8606-6, Town, and BE7149, showed resistance and will be used for further testing.

The 70 entry ADIN (All Disease and Insect Nursery) was evaluated under natural infestation for anthracnose and sooty stripe at Sotuba with several lines showing useful levels of resistance.

Striga

Cultivars from the Malian Collection (Seguetana), selected lines from Dr. G. Ejeta, Purdue University and from the national breeding program were used in the *Striga* evaluation field trials in 1993. Among the cultivars collected in southern Mali, the best six, CMDT 30, CMDT 39, CMDT45, CMDT48, CMDT76, and CMDT115, showed less *Striga* incidence than the check Tiemarifing.

At Samanko and Katibougou, selected F_5 breeding lines (Malisor 84-7*SRN39) from Purdue were as resistant as the resistant check, Tiemarifing, in preliminary screening trials. Six advanced generation lines (SRN39*Zerazera) developed and selected at Purdue for resistance to *Striga asiatic* were tested on-farm in the Katiabougou area. All showed high levels of resistance to *S. hermonthica* and 92PR-203 also showed excellent agronomic traits.

At Cinzana, a reportedly resistant local guinea landrace variety, Seguctana Cinzana, showed excellent resistance in a field screening nursery. This line will be studied in the Purdue Lab.

Crop Production/Agronomy Physiology Soils

Seedling Screening for
Drought and Heat Tolerance

Selected early and intermediate maturity advanced including breeding lines were tested for high heat and drought tolerance in the 92-93 off-season in charcoal pits at Cinzana. In the early trial 87-LO-F_4-92 (Malisor 84-1), 88-CZ-F_4-173-3, 89-CZ-CS-F_5-126AF and Bagoba were tolerant. Malisor 92-1 had the highest plant survival at the 3rd, 7th, and 15th day after planting. In the intermediate maturity trial, 90-CZ-CS-104 and 90-CZ-CS-F5-65 showed good seedling survival.

Peanut-Sorghum Rotation

In 1993, previous peanut crop effect was very important to sorghum grain yield. There was a 74% increase due to previous peanut cropping alone at zero N level, and 114% and 102% yield increase when 40kg and 80kg of N were applied to previous peanut plots. Other results have indicated that the rotation effect is not due only to legume N effect.

Sorghum-Peanut Intercropping

The land equivalent ratio (LER) is used as a land use efficiency indicator. The efficiency of sorghum peanut intercropping in 1993 was estimated at 1.48. The yield of sorghum grain in intercrop was 48% of sole sorghum and that of intercropped peanut was 100% of the yield of sole peanut crop. Rotations with sorghum-peanut intercrop, compared to sole sorghum, showed a 36% yield increase of sorghum grain in the rotation compared to sole sorghum.

Cowpea - Pearl Millet Rotation

Previous cowpea had a significant effect on pearl millet grain yield. At the zero N level there was a 56% yield increase. This increase was more than the effect of 20kg N/ha (15% increase) and equivalent to that of 40kg N/ha (56% yield increase). Combined nitrogen and previous cowpea was even greater with yield increases of 67%.

Pearl Millet - Cowpea Intercropping

The land equivalent ratio (LER) of millet-cowpea intercrop indicated a 55% yield increase in total production. Partial LER of pearl millet grain yield over nitrogen levels was 100% for zero and 85% and 73% for 20 and 40 kg N/ha. The rotation effect of millet-cowpea intercrop on succeeding sole millet was a positive 14% without N application.

Long Term Residue Management Study

A residue management study on sorghum and millet monoculture and rotation of cereal-legume was initiated in 1990 with three residue treatments: removed; leaving residue on soil surface; and incorporated. There was no effect on grain or stover the first three years, but in 1993 grain yield differences occurred for the first time. For both crops, incorporated and removed were superior to leaving residue on the surface. The consistent lower yields where residue was maintained on the surface could be due partially to an observed reduction in stand. The crop residue treatments showed no effect on peanut and cowpea yields.

Biomass-Harvest Index Study

Different planting dates and different fertilizer levels had no significant effect upon total biomass or harvest index of 15 local Malian varieties. Similar results were obtained on a similar study of five advanced Malian breeding lines.

Sorghum Photosensitivity Adaptation Study

Three Guinea types and three non-sensitive improved cultivars were planted every 15 days from May to the end of July. The days to flower changed for the Guineas until the last two dates, while the nonsensitive lines showed little effect upon days to flower. The Guineas flowered earlier with the later planting dates.

Sandy Soil Toxicity on Sorghum Study

This InterCRSP activity among IER, INTSORMIL, and the Soil Management CRSP involved evaluation of sorghum genotypes for tolerance in field plots at Cinzana. In 1992, F_2 population involving Bagoba, Babadia Fara, and Gadiaba consistently showed tolerance. In 1993, 46 cultivars were evaluated in the same plot, and under very severe conditions, the northern Mali durra cultivar, Cadiaba (Cinzana) consistently showed genetic resistance to this soil problem. Analyses of soil next to individual plants by the Soil Management CRSP was done to attempt to determine the cause of the extreme spatial variability.

Grain Quality Studies

Breeding Line Evaluation

The advanced medium maturity trial and early trial grain samples were evaluated in the Cereal Technology Lab for kernel characteristics, physical properties, decortication yield, and tô properties. The early materials generally had a slightly lower decortication yield. In general, all gave good tô color and quality. The preliminary trials from Cinzana and Bema were also analyzed. Data are used by breeders in making decisions to discard or keep test entries.

Couscous Preparation Survey

A study was conducted in Bamako to determine parameters important in couscous preparation, using 117 women from 14 different ethnic groups. The sorghum variety was consistently an important consideration in couscous quality. Large white seed which decorticates easily, with high flour yield, produces good couscous. Other factors important to couscous quality are flour textile, grain mold, making fashion, water quality, type of steamer, steaming time, and mucilage type.

Seed Germination

The seed laboratory germinated 537 samples of sorghum from the entomology program to study the effects of head bug and grain mold/weathering. Only 43% of the samples gave excellent germination. There were large differences among genotypes.

Economics

Ousmane Coulibaly, a Malian Ph.D. student at Purdue, initiated his thesis fieldwork in Mali on a study of technologies to increase water availability and soil fertility in the Sudanian and Sudano-Guinean zones of Mali. He also assisted IER scientists in their evaluation of the economic effect of a fungicide application for downy mildew control on pearl millet.

Niger

Collaborative Program

This is an interdisciplinary, multi-institutional collaborative research program which involves INRAN and U.S./INTSORMIL institutions.

A major sorghum and millet workshop was sponsored in 1985. This workshop demonstrated the quality research and collaboration that had taken place not only between INTSORMIL and leading INRAN scientists but also between the Soil Management CRSP, ICRISAT Sahelian Center, the USAID/Purdue/INRAN National Cereals Research project, the International Fertilizer Development Center (IFDC), and CILSS. This workshop provided significant interaction between scientists and other workshop participants and served as a model of cooperation and collaboration on resolving constraints to improved production and utilization of sorghum and millet. USAID provided core funding and local support for this workshop.

The ICRISAT Sahelian Center has been actively involved in millet entomology and millet breeding research. Participants include Drs. Frank Gilstrap, Ousmane Youm, Ouendeba Botorou and Anand Kumar. Dr. Wayne Hanna, in Georgia, has also been an active collaborator in this millet program. In the past 14 years, there have been other organizations and International Centers who collaborated with our program in Niger. These include the Soil Management CRSP, the Agricultural Research Corporation in Wad Medani, Sudan, IN.E.R.A. in Burkina Faso, and the Purdue/Niger Applied Agricultural Research (NAAR) project.

There are several interdisciplinary activities involved in this program. These include sorghum and millet breeding, agronomy, pathology, physiology, food quality and economics. U.S. INTSORMIL Principal Investigators develop research plans and budgets with INRAN collaborators on an annual basis. Each plan is then translated into French and submitted to Dr. Mamadou Ouattara, INRAN Director General, for his approval.

Production and Utilization Constraints

Drought, insect pests, long smut and *Striga* are the major constraints in Niger. Extremely high soil temperature leads to difficult problems in crop establishment. Sand blasting of young seedlings is also a complicating factor. Plant breeding for tolerance to these major constraints is one of the most feasible solutions. New cultivars must be acceptable for tuwo preparation. For example, the variety L-30 has been the highest yielding sorghum variety in the Sahelian trials for the past 10 years, but is not accepted by farmers because of poor food grain quality. A number of useful collaborative research activities have been developed in Niger between INTSORMIL principal investigators and INRAN scientists.

Research Progress

The sorghum and pearl millet breeding programs are only two examples of research progress findings. The INRAN sorghum breeding program has made significant progress in its own organization and in the results obtained over the years. INTSORMIL is recognized within INRAN as a great contributor to all of that success. Among other things, INTSORMIL researchers have provided professional assistance in the field and in academic training to many INRAN workers. The improved sorghum varieties SRN-39, NAD-1 and SEPON-82 (adopted by a large number of farmers) are clear examples of what this collaboration has yielded to farmers in Niger. This needs to be continued and strengthened. Genetic materials, with overall adaptation, are still needed and may come from the kind of productive exchange we have had thus far. Presently, there is a good number of improved lines which need further tests and improvement for traits like stand establishment, lodging resistance, or resistance to *Striga*.

A major study of pearl millet breeding strategies for Niger was conducted by Dr. Ouendeba Botorou with the following conclusions: the results of the diversity and diallel cross studies indicate clearly the knowledge of the degree of similarity or dissimilarity among landraces is not sufficient when choosing the best parent for crosses. The population crosses Ex-Bornu xP3Kolo gave the highest grain yield and a good level of heterosis even though the cluster analysis showed that the two cultivars had similarities for most of the traits measured.

Research Accomplishments

Socioeconomics - Abdoulaye Tahirou, Mohamadou Abdoulaye and J. Lowenberg-Deboer

During the 1993 agricultural season, the socioeconomics component of the INRAN/INTSORMIL collaborative research program has continued the investigation of sorghum by-products. The general objective of the study is to determine how by-products affect farmer decisions. This second year of data collection is intended to give a dynamic view of the system.

Data were collected in Dagarka and Kaku, the same two villages in the area of Birni N'Konni that were surveyed in 1992. The same 23 farmers were interviewed. Sorghum by-products were found to be an important part of the agricultural system in the area of Birni N'Konni. They are important in animal nutrition, and farmers get a certain cash revenue from them.

The average value of the sorghum stover at harvest (October) was 7752 fcfa per hectare. If the farmers can store their sorghum stover production until March, the average value is almost doubled to 14535 fcfa per hectare. Sorghum stover and stalks are commonly used for forage and energy. They are also used for fences and making beds. All the farmers in the sample report the use of sorghum stover as forage, about 80% for energy, 10% for fences and 25% (all at Kaku) for bed construction. Sorghum bran is used mainly for animal nutrition or sold.

Less than 30% of farmers interviewed in both villages responded that they could leave part or all the sorghum stover they produced on the field to help control wind erosion and/or maintain soil fertility. Farmers know that this can help control erosion, but the use of the stover short term benefits are important in this subsistence farming system.

Although many aspects are taken into account for the choice of a sorghum variety, the first criteria tends to be the overall grain yield. Other aspects farmers look at when choosing a variety include: the color (especially the flour), the hardness of the grain (bran is more easily removed without damaging the grain from hard grains), the color of the stover and its quantity after the harvest.

It is essential that future economic evaluation of technologies in this area take into account the value of sorghum stover. Sorghum production in this area is mainly carried out through an intercropping system with millet and cowpea. Agronomic evaluation on-station or on-farm can help identify varieties suitable for intercropping.

Data collected in this survey are being used to develop a representative farm model for this area which includes both crop and livestock activities. The interaction between these two activities among Nigerien farmers is becoming more important especially now with the devaluation of its currency making imported inputs more expensive.

Entomology - Hame Kadi-Kadi, Ousmane Youm and Frank Gilstrap

In 1993, discussions were held with Mamadou Ouattara, Ouendeba Botorou and Hame Kadi-Kadi (INRAN), Ousmane Youm (ICRISAT), I. Bayoun and F. Gilstrap to develop collaborative plans to assess the sources of mortality for the millet head miner (MHM) in Sadore and Maradi. These plans called for Mr. Kadi-Kadi to come to ICRISAT-ISC in September-October, 1993, and receive short-term training from Mr. Bayoun and Dr. Youm on methods and techniques needed for 1994 research. However, Mr. Kadi-Kadi was unable to participate in the training. The work reported below was conducted entirely on and near the facilities of the ISC.

The millet head miner (MHM), *Heliocheilus albipunctella* (de Joannis), commonly causes significant crop losses of pearl millet, *Pennisetum glaucum* L., a primary food crop in Sahelian West Africa. MHM is an excellent candidate for demonstrating a control strategy that emphasizes effective natural enemies. It occupies a predictable habitat in an ecosystem with relatively consistent annual habitats, has one generation per year, attacks several host plants including wild millet, and across West Africa supports a relatively large guild of natural enemies. The objective of this research is to evaluate natural enemies of *H. albipunctella*, and the results will serve to appraise tactics and develop a biological control strategy for *H. albipunctella*.

The following research is needed before biological control can be used as part of an integrated management strategy that deals effectively with MHM. During 1993-1996, collaborative exclusion studies on MHM developmental stages in Sadore and Maradi will be conducted and the data will be used to construct life tables for MHM. The 1993 research will provide baseline methods and initial results for planning 1994 experimentation. The 1993 experimentation consisted of cage exclusion studies and population monitoring at Sadore.

Exclusion experiments are essentially a series of paired plots in which natural enemies are excluded from one-half, and are allowed access to the other one-half (Control or Check). Survival is measured in all plots, and the differences between treatments are a direct measure of the natural enemies' controlling impact. Treatments can be modified in many ways to collect different kinds of pest mortality information. In 1993, caged exclusions that consisted of placing a physical barrier (i.e., panicle cage) over panicles in the plots were used. Openings were made in one-half of these cages to permit natural enemy ingress and egress. Different types of cage treatments were set up to evaluate enemies occurring on different MHM stages (i.e., eggs, early and late instars) separately. Treatments included (1) cages closed throughout panicle development, which excluded all natural enemies; (2) cages opened only during the egg stage, and then closed until the end of the season; (3) cages opened only during early MHM instars, and then closed until the end of the season; (4) cages opened only during development of late MHM instars; and (5) cages opened throughout panicle development. At the end of the season, millet heads were cut and MHM were counted.

Results showed attacks by natural enemies have a very significant impact on mortality of MHM, and most of this mortality occurs during the late larval stages. Cages opened throughout panicle development had the same total number of surviving MHM individuals as closed cages. A significant finding from this first year of data is that we encountered relatively few species of enemies attacking MHM. Two predators and two parasites were the most commonly recovered natural enemies.

The two most common predator was Orius sp., a small anthocorid predator that attacks MHM eggs and early instars. The second most common was an ant that attacked full-grown larvae after they dropped to the soil to pupate.

The two commonly encountered parasites were both parasitic Hymenoptera. The most common parasite was an encyrtid, *Copidosoma* sp., an egg-prepupal parasite that attacks the MHM eggs and emerges as an adult from the MHM prepupa. This parasite is polyembryonic, i.e., one parasite egg produces offspring. An average of 394 (maximum = 802) adult parasites emerged from each parasitized MHM. The second most common parasite was a braconid, *Bracon hebetor*. *Bracon* is a gregarious ectoparasite that attacks late larval stages of MHM. Parasitism by *B. hebetor* occurs mostly late in the season, and can reach 80-90% of the total MHM population. Female *B. hebetor* attack late MHM instars, permanently paralyzing them. Some attacks result in the parasite ovipositing eggs externally on the MHM host. Studies in 1993 encountered many larvae killed by *B. hebetor* but without parasite eggs. Thus, *Bracon hebetor* functions ecologically both as a predator and as a parasite. *Bracon hebetor* has a short generation time and is polyphagous.

In 1994, the team will continue these experiments, and conduct additional experiments as needed for an age-specific life table for MHM. These experiments will take a natural cohort of MHM and follow it through to the end of the season and then to the next season. They will then construct survival budgets for MHM, and characterize the portion of MHM population removed by natural enemies. Their research approach will consist of host exposure techniques, caged exclosures and natural population monitoring.

Cereal Quality - Moussa Oumarou,
Adam Aboubacar and Bruce Hamaker

The Cereal Quality Laboratory (LQC) at INRAN has conducted several surveys to determine the different methods of couscous preparation used in Niger. Two different locations were selected for the surveys. In one location (Maine-Soroa), three types of locally grown cereals (sorghum, millet and durum wheat) were used to produce couscous using the preparation method of that location. All three cereals were processed the same way and produced acceptable couscous. In the other location (Tera), couscous was produced using three millet varieties (C.I.V.T., SOUNA 3, and H.K.B. Tif) grown in 1992 at the Kollo station.

Four different processing methods were used to produce couscous and a macaroni type product. Two of the procedures, one for couscous and the other for macaroni were different from the other two only in the fermentation step. A sensory panel was used to evaluate the different products and their quality was found to be improved by fermentation. All processing steps were recorded in order to determine the best method(s) that could be used for a commercial production of couscous.

The LQC has also conducted a study on composite flour breads. Breads were made in collaboration with a local bakery at Niamey, using a blend of 10, 20, 30, and 40% sorghum and millet flour with wheat flour. The results showed that incorporation of millet or sorghum flour up to 20% gave acceptable bread. At higher concentrations, the bread was heavier and tended to break easily. It was also found that increasing the proof time increased loaf volume. A sensory evaluation study indicated that consumers preferred the incorporation of millet flour over sorghum. Demonstrations of bread from composite flour were made to processors and government officials at a workshop organized by INRAN in Niamey.

Sorghum Breeding - Moussa Adamou,
Issoufou Kapran, Gebisa Ejeta and John Axtell

During the summer of 1993, several trials were conducted at the main INRAN stations at Maradi and Kollo, while *Striga* resistance testing was conducted at the Konni station. In addition, demonstration plots were conducted by a large number of farmers, especially around Maradi and Konni. In all cases, the results were very satisfactory, with new elite material being observed on-station and farmer interest in the demonstration plots on the rise. It was therefore decided to keep the breeding project at least at the same level of activity for 1994. For this crop season, most of the genetic material was provided by the Purdue University/INTSORMIL program, and some was also provided by Nebraska.

The germplasm from Purdue covers many aspects of sorghum improvement, including early generation material for pedigree selection, elite lines for adaptation/observation in Niger, hybrid yield trials to evaluate the performance of new R and B lines, on-station testing of new *Striga* resistant lines and a *Striga* resistance population, and aspects of hybrid seed production and on-farm testing. Following a conversation with I. Kapran, Prof. David Andrews provided some new lines and hybrids for comparison with other INRAN/INTSORMIL germplasm. Conduct of these trials and nurseries was discussed in early June 1994 at Niamey, Kollo and Maradi between I. Kapran and Dr. Moussa Adamou, Issoufou Kollo for the *Striga* tests, and the two sorghum technicians M. Abdou and N. Kondo. Except for Kapran, on study leave at Purdue, these individuals are primarily responsible for the field work in Niger. Actual planting was started toward the end of June, and to date the rainfall figure has been exceptionally high in almost all of Niger. In fact, flooding has occurred on the heavier soils of the two main INRAN stations at Kollo and Maradi, as well as on some of the on-farm plots. Still, preliminary observations suggest that at least on the drier soils, nurseries will provide interesting data. Experimental hybrid seed production continues at several locations to provide more seed for future demonstration plots, as well as mastering the best nicking scheme between the parents of NAD-1 hybrid. Field days are once again scheduled for early October to provide more farmers the opportunity to visit other demonstration plots and research plots in nearby INRAN stations.

Plant Pathology - Issoufou Kollo
and Richard Frederiksen

Cooperation with ICRISAT was continued through the joint International Anthracnose Virulence Nursery. The enhanced collaboration stems from the recognition of the importance of this disease in the more humid sorghum growing regions of the developing world. Anthracnose collaboration permits the better evaluation of the durability of host resistance and a better estimate of the variation in pathogenicity among isolates of the pathogen worldwide. Participating regions include West Africa, Mali and Niger; East Africa, Sudan; Southern Africa, Zambia and Zimbabwe; and Brazil. INTSORMIL research has demonstrated that there is tremendous variation among isolates from locations and between locations. Sorghum downy mildew has become less and less of a problem because of global cooperation in the development of host resistance, characterization of isolates and through the use of highly effective fungicide seed dressings. RFLP and RAPD markers linked to head smut, downy mildew, and acremonium wilt resistance have been placed within specific linkage groups on the sorghum genome.

INRAN's sorghum program has released to the Niger Extension Service two grain sorghum open-pollinated varieties and one hybrid for the heavier and better structured soils with more than 500 mm rainfall. These improved varieties, Sepon-82 (=M90382) and SRN-39 (=ICSV1007BF), were developed in collaboration with INTSORMIL and ICRISAT. The hybrid is designated NAD1 and has ATX623 as female parent and MR-732 as male restorer. Mean grain yields of the three improved cultivars from yield trials at different sites in Niger from 1986 to 1991 were submitted to yield stability analyses by regression against the yield of the local variety. For Sepon-82 there were 67 data points available with yields ranging from 370 to 3780 kg/ha. The hybrid NAD1 had 27 data points with yields ranging from 580 to 5340 kg/ha. SRN-39 had 14 data points in *Striga*-infested fields [*Striga hermonthica* (Del.) Benth.] and 22 in non-infested fields with yields from 310 to 3130 kg/ha. Simple linear regression was computed for each cultivar. The intercept and the slope for Sepon-82 regression line did not differ significantly from the equal yield situation, but was completely above the equal yield line, indicating that it is at least as stable for grain yields as the local variety. The intercept of NAD1 was significantly higher (p) than the equal yield situation but the slope was not significantly different, meaning that the hybrid outyielded the local variety by 482 kg/ha even in the low yield environments. The low correlation of grain yields of SRN-39 and the local variety in non-*Striga*-infested fields gave an intercept and slope not significantly different from the equal yield situation. In *Striga*-infested fields the intercept was significantly higher, with a mean grain yield advantage of 974 kg/ha by SRN-39 over the local variety. Therefore SRN-39 yielded more in *Striga*-infested fields and was at least equal in the absence of *Striga*. SRN-39 appears to be less adapted to the higher rainfall zone of Niger (800 MM+), where it yielded consistently less than the long-cycle local variety. The cultivars NAD1, SRN-39 and Sepon-82 have proven to be well adapted to Niger's severe climatic conditions and produced better grain yields than local varieties, even under unfavorable conditions.

Sudan

Collaborative Program

Organization

The INTSORMIL/U.S. principal investigators develop their scope of work jointly with ARC scientists. These workplans are reviewed and approved by Dr. Badir Salim, ARC Director General; Dr. El Hilu Omer, ARC/INTSORMIL Coordinator and Dr. Gebisa Ejeta, Sudan Country Coordinator, and become part of the INTSORMIL Memorandum of Agreement.

Each workplan has its own funding. Funds are forwarded directly from Purdue University or the INTSORMIL Management Entity at the University of Nebraska and then disbursed in Sudan to each ARC scientist to carry out his research program.

Dr. Ejeta and Katy Ibrahim coordinate the management of this program with U.S. principal investigators at Texas

A&M, Nebraska, Mississippi State, and Purdue Universities.

Since direct communication with Sudan is basically nonexistent, the USAID Mission has provided excellent logistical support to relay communication to the ARC at the Wad Medani and El Obeid research stations.

Collaboration with Other Organizations

The INTSORMIL/Sudan country program continues to collaborate with the following host country and U.S. organizations:

Agricultural Research Corporation (ARC)
Gezira Research Station (GRS)
Kadugli Research Station
Food Research Centre, Shambat
Sudan National Seed Administration
El Obeid Research Station
USAID/Khartoum
University of Nebraska-Lincoln
Texas A&M University
Mississippi State University
Purdue University

The Scope and Thrust of the Program

Production and Utilization Constraints

The potential for expansion of sorghum in the rainfed areas of Sudan is enormous; however, the major constraints limiting expansion are inadequate soil moisture, inadequate soil nutrients, and shortage of labor. Other factors that reduce sorghum yields in Sudan include insect pests, plant diseases, and *Striga*. High yielding cultivars with good grain quality suitable for mechanical harvesting are also requirements for future expansion of sorghum in the rainfed central clay plain regions of Sudan.

Breeding efforts currently under way in Sudan to incorporate drought tolerance with higher-than-average yield potential in sorghum are limited by the lack of a rapid field screening procedure and lack of knowledge on sources of sorghum germplasm with useful traits. The insect pests known to attack sorghum, especially in the rainfed areas of Sudan, include stem borers, American bollworm, and central shoot fly. The major fungal diseases that affect sorghum production in Sudan include charcoal rot, anthracnose, long smut and a variety of grain molds. *Striga*, a parasitic weed of sorghum, constitutes a major constraint to sorghum production in Sudan. There is very little sorghum germplasm with resistance to *Striga* and the mechanism that renders resistance to *Striga* is not well understood. Knowledge about the inheritance of this trait is also lacking. The lack of absolute definitions and good screening methods for food quality to some extent also limit the utilization of high yielding sorghum varieties and hybrids in Sudan. Work on all these aspects is needed to improve sorghum production and utilization in Sudan.

Almost all of the pearl millet grown in Sudan is used for home consumption by farmers in Western Sudan. The exception is a small but growing activity of millet cultivation in the mechanized rainfed regions where millet is produced on fields where sorghum yields have fallen too low. In Western Sudan, the crop/bush fallow system of production has traditionally been used to provide enough nutrients and possibly some moisture for a period of crop years (5-10 years fallow/2-4 years cropping). Crops are often grown in an intercropping system with millet to maximize production. Over the last 20 years, rainfall has declined, thus reducing the soil recovery rate during fallow. Fallow periods have also decreased due to higher human and animal pressure on plant cover, further aggravating the loss of moisture, nutrients and soil structure. As a result, there has been further reduction in millet yields. Accordingly, the primary constraints to millet production in Western Sudan are lack of moisture and soil nutrients, and poor husbandry. Crop losses to insect pests (Raghuva), and diseases and *Striga* are also important factors limiting millet production.

Research Progress

Sorghum Breeding
Osman El Obeid Ibrahim

During the 1993 crop-season, the sorghum breeding program at Gezira Research Station (GRS) ARC, continued to concentrate on hybrids and varietal development and evaluation. Major emphases were placed on hybrids and varieties with multilocation testing. The varietal breeding nurseries included new crosses, establishment of F_1 plants, advancement of segregating generations and evaluation of converted lines, drought tolerant parental lines and backcross progenies as part of ARC/ INTSORMIL Collaborative breeding research. Varietal trials at GRS included evaluation of advanced (36 entries) and preliminary (176 entries) trials for yield potential and/or drought tolerance.

The hybrid breeding nurseries included evaluation of new parental lines and synthesis and evaluation of new experimental hybrids. The hybrid trials included advanced (72 entries) and preliminary (144 entries) tests. The ARC/ INTSORMIL collaborative joint trial for the 1993 crop-season, contained 126 sorghum hybrids and their parental lines, and was conducted under irrigation and rainfed situations at GRS.

As a result of several years of on-station varietal and hybrids development and evaluation, several promising experimental varieties and hybrids were identified and advanced to on-farm and standard levels of multilocation trials during the 1993 crop-season. The on-farm test contained one hybrid and two open pollinated varieties. The standard test included 11 varieties and 15 hybrids. Multilocation testing was extended to cover eight irrigated and four rainfed locations. Two open pollinated varieties and one hybrid, showed good and stable yields, namely 89/OSFS 2431 under irrigation and high rainfall zones, P-967083 under Jebel Marra conditions, and 89/OSH 5283 under irrigation. These cultivars will be considered for submission to the National Variety Release Committee, hopefully, during 1994-95.

As a result of intensive breeding work in the last ten years, several promising elite varieties and hybrids have been accumulated in the program. However, testing of these materials has been restricted to limited numbers of locations and agroecological zones in the country. There is a pressing need for intensifying the testing program to cover more locations and agro-ecological zones, especially in traditionally sorghum-growing rainfed areas, where the bulk of the crop is produced. Another factor slowing or discouraging the release of new products, especially hybrids, is the lack of a viable seed industry. Farmers, especially in irrigated production areas, have come to highly appreciate the concept and value of pure and or improved seeds, which should encourage the development of seed industry in the country.

Striga Research

A.G.T. Babiker, S.M. Eltyeab and M.T. El Mana

On-farm and on-station trials were undertaken on irrigated and rain grown sorghums. The objective of the on-station trials was to develop control measures which are effective during the early subterranean stages of the parasite growth. The objective of the on-farm trials was to demonstrate to farmers and extension workers the technical feasibility of some of our previous findings.

Sorghum trials were planted in an artificially *Striga*-infected plot. Improved lines obtained from Purdue University, as well as local popular high yielding varieties were used. Urea (190 kg/ha) was applied at planting. Chlorsulfuron (2.4g/ha) was applied 4 weeks after planting as a soil directed spray. *Striga* count was made 75 days after planting. Lines tested were PR 227, PR 239, PR 269 and PR 293. Dabar (*Striga* susceptible) and SRN 39 (*Striga* resistant) were included as controls. *Striga* population density varied between 7 and 39 plants/m^2. PR 269, PR 239 and SRN 39 sustained the lowest emergence (7-14 plants/m^2) while Dabar had the highest emergence (39 plants/m^2). Urea reduced infestation by 52 to 86%. Infestation on PR 269, PR 239 and SRN 39 was the most reduced, while that on Dabar was the least affected. Chlorsulfuron reduced *Striga* infestation by 68 to 94%. The herbicide suppressed *Striga* infestation about equally on all varieties, except on PR 293. *Striga* reduced crop stand. Dabar was the most affected, while SRN 39 was the least. Urea mitigated the adverse effects of *Striga* on sorghum in all varieties, except on Dabar and on PR 293. Chlorsulfuron, on the other hand, resulted in a substantial increase in crop stand, irrespective of the variety used. The parasite delayed heading in all varieties. Urea and chlorsulfuron, invariably, increased the number of heads. Among all varieties, Dabar and PR 293 were the least responsive to the herbicide and fertilizer. SRN 39, PR 227 and PR 269 showed about equal response to both herbicide and fertilizer. *Striga* reduced straw yield of all varieties. Untreated SRN 39 and PR 269 had the highest straw yield, while Dabar and PR 293 displayed the lowest yield. Urea and chlorsulfuron mitigated the adverse effects of *Striga* on straw yield. Dabar and PR 293 displayed a low response to urea, while PR 269 was highly responsive. Across varieties, chlorsulfuron was more effective than urea.

The local varieties Gadam EL Hamam, AjabSedo, Iriana, Korakolo; Safra, SRN 39 and Tetron were tested in a separate experiment. Compared to the *Striga* resistant variety (SRN 39), the local varieties supported two to three fold greater *Striga* emergence. *Striga* emergence was reduced by both urea and chlorsulfron. The suppressive effects of urea on *Striga* emergence was negligible on Ajabsedo, moderate on Iriana, Korakolo and Gadam EL Hamam and was good to excellent on Safra, Tetron and SRN 39. Chlorsulfuron was more effective against the parasite than urea. *Striga* emergence was moderate on AjabSedo and Iriana, low on Gadam EL Hamam, Korakolo and Safra and was negligible on Tetron and SRN 39. The stand of all varieties, except SRN 39, was reduced by the parasite. The highest reduction was displayed by AjabSedo, while moderate losses were exhibited by Iriana, Korakolo, and Safra. Urea, substantially, improved the stands of Korakolo, Iriana and AjabSedo. However, its effect on Safra was negligible. The herbicide improved stands of most varieties with more pronounced effects on Gadam EL Hamam, AjabSedo and Safra. Sorghum heading was considerably curtailed by the parasite as only 25 - 69% of plants produced heads. SRN 39 was the least affected. Urea and Chlorsulfuron improved heading in all varieties. Safra and Korakolo displayed the lowest and highest response to urea, respectively. Chlorsulfuron was more effective than urea. Among varieties, Gadam EL Hamam, AjabSedo, Iriana, Korakolo and Safra displayed the highest response. The parasite reduced straw yield of all varieties. Urea increased straw yield by 70 to 140%. Gadam EL Hamam, SRN 39 and Tetron were the most responsive. Chlorsulfuron increased straw yield by 80 to 560%. Chlorsulfuron-treated Tetron and SRN 39 gave the highest yield.

In yet another test, the hybrid Hageen Dura-1 (HD-1), Gadam EL Hamam, Dabar, AbuSabeen, Tozi Umbenein, SRN 39 and Mogud were evaluated. Emergence of *Striga* varied between 10 and 21 plants/m^2. The highest emergence was supported by AbuSabeen, Tozi Umbenein and Gadam EL Hamam. SRN 39, on the other hand, supported the lowest emergence. Urea reduced *Striga* infestation on all varieties except HD-1. *Striga* suppression varied from moderate (52%) on AbuSabeen to excellent (95%) on SRN 39. Chlorsulfuron effectively reduced *Striga* emergence on all varieties. Complete suppression of the parasite was achieved on SRN 39. *Striga* reduced crop stand. The observed losses were negligible on SRN 39 and Tozi Umbenein, but were severe on HD-1 and Abu Sabeen. Urea and Chlorsulfuron improved stand on all varieties except HD-1. *Striga* reduced heading in all varieties. Losses due to the parasite were heavy (78-79%) for HD-1 and Abu Sabeen and were negligible for Tozi Umbenein and SRN 39. Urea and chlorsulfuron increased heading in all varieties. Heading in HD-1 and Abu Sabeen was increased by two to four fold. The parasite reduced straw yield of all varieties except SRN 39 and Tozi Umbenein. HD-1, Abu Sabeen and Dabar displayed the highest losses. Urea and chlorsulfuron mitigated the adverse effects of *Striga* on straw yield, particularly that of the susceptible varieties. Straw yield of Abu Sabeen was increased by two to four fold.

An on-farm trial, in collaboration with the extension service, was undertaken at El Rawashda, a village north of Gadaref town. Sorghum (CV. Korakolo) was planted in early August, with rows 80 cm apart and spacing within the row 10 cm apart. The crop was later thinned to single plants per hill. Sorghum treated or untreated with urea at planting, was sprayed with a tank mix of chlorsulfuron (2.4g/ha) and dicamba (300 g/ha) or left untreated. The herbicides were applied as soil directed sprays, four weeks after planting. Sorghum planted late August was included as a control to reflect the farmers practice of late planting in *Striga* infested areas.

Sorghum sown early August was heavily infested by *Striga* (73 plants/m^2). Late August sown crop sustained a lesser infestation (25 plants/m^2). The tank mix of chlorsulfuron and dicamba, when not preceded by urea, effected 83% control. Urea treatments made prior to herbicide application increased herbicidal efficacy (95% control).

Untreated early sown sorghum gave low yield (0.39t/ha). Late planting of sorghum effected a higher yield (0.6t/ha). The tank mix of chlorsulfuron and dicamba, irrespective of the preceding urea treatment, increased sorghum yield to about 0.8 t/ha.

Sorghum-Millet Pathology
El Hilu Omer

Screening of Sudan germplasm for resistance to long smut was continued this season. Five hundred entries were planted as single lines and at boot stage were inoculated in the standard method reported before. Twenty cultivars were fairly resistant. These will be subjected to further confirmation tests during the 1994 season. None of the 21 cultivars introduced from Egypt and Syria proved tolerant to long smut.

Disease survey in six districts of Kordofan State indicated that downy mildew (*Selerospora graminicola*) on pearl millet is the most serious disease. Infection ranged from 16-80%. It was more prevalent in high rainfall areas, getting less in drier areas. Ergot (*Claviceps fusilformis*) and smut (*Tolyposporium penicillariae*) are second to downy mildew in importance. Grow-out of farmers varieties, in Gezira Research Station, indicated that the seed plays a primary role in disease spread.

Sorghum Entomology

Four seed treatments were compared for assessing damage incurred to sorghum by insect pests before emergence and throughout the seedling stage. The most serious pests considered were mole crickets, termites, cutworms, soil weevils and to a lesser extent, white grubs. The seed dressings tested were Promet at 0.3, 0.4 and 0.5 ml/10 kg; Gaucho at 150, 100 and 80 g/100 kg and Lindane (standard) at 150 g/100 kg. An untreated control was added for comparison. The trial was carried out at Sim-Sim and Rahad Research Station. Row spacing was 60 cm. and 10 cm. between plant holes and 3 seeds/hole were used in replicated trial.

Higher rates of Promet, Lindane and all rates of Gaucho gave good crop establishment and were significantly better than the untreated control but were not dissimilar to the standard. However, insect infestation was remarkably higher in rainfed areas compared to irrigated Rahad. In Rahad, delayed sowing gave higher infestation compared to optimum sowing date. Early sowing under irrigation, irrespect of the treatment, gave higher grain yield; 4517 kg/ha for July sowing as compared to 3048 kg/ha for August sowing.

Among chemicals tested for control of American bollworm, Damazine Thiodan 35 ULV at 2.38 l/ha was the best chemical for control of the pest and gave a significant higher yield than the unsprayed control. None of the 14 tested varieties and promising cultivars showed tolerance to stem borers but, HD-1 gave the lowest infestation.

Botswana/Southern Africa

Collaborative Program

The INTSORMIL collaborative research program in southern Africa is in transition from using an expatriate scientist to coordinate activities in Botswana to direct INTSORMIL U.S. Principal Investigators collaboration with host country scientists in several southern Africa countries. This transition has been slow because of budgetary constraints and logistical/communication difficulties.

Organization

After termination of the ATIP project which included financial support for the expatriate scientist, the new mode of operation for Botswana and southern Africa was for U.S. and host country scientists to form joint partnerships and prepare research proposals to access INTSORMIL funds allocated for this region. Unfortunately, these funds were eliminated because of INTSORMIL funding constraints, thus, collaborative research during 1993-94 was direct scientist to scientist collaboration with funding coming from U.S. INTSORMIL Principal Investigators budgets. These results are presented in the individual project reports.

Sorghum/Millet Constraints Researched

Sorghum and pearl millet are important crops in the SADC countries, with both grain and stover being widely used. The grain is used mainly for human food, but some grain and the stover are used as livestock feed. During the 1980s, farmers yields have averaged less than 500 kg ha^{-1}. These low yields partially reflect crop failures when no grain was harvested. It also reflects the low natural level of soil fertility, and the limited use of fertilizers and/or crop rotation. To reach the critical yield level of 1.5 to 2.0 Mg ha^{-1}, a crop uptake of 45 to 60 kg ha^{-1} N, and 16 to 20 kg ha^{-1} P is required regardless of the cultivar or production practices used.

The low, irregular, and low-efficiency rainfall patterns of the region combined with sandveld and hardveld soils with low water retention and poor weed control also contribute to the low yields of sorghum and millet. In some instances, broadly soil texture fractions, (i.e., coarse sand, fine sand, silt, clay) and unstable surface soil properties result in a high bulk density (compaction) when dry, and surface sealing with crust formation. This slows the infiltration rate of rain and limits crop root penetration.

Water conservation and redistribution technologies, soil fertility improvement, residue incorporation, and weed control are urgently needed to improve soil structure and water conservation for crop establishment, and production of higher grain and stover yields.

Research Progress

There are two large, distinctly different clientele for sorghum production in Botswana. One is the small family farmer who uses sorghum primarily for food and brewing, and the other is the large farmer who has the resources to utilize hybrid sorghum seed, fertilizer, and large equipment for sorghum production. The latter is generally located in the Pandamatenga region.

Several sorghum hybrids, and sorghum and pearl millet varieties are scheduled to be released soon. They all will be cultivars with good food quality characteristics, and are presently being rated for insect and disease resistance/tolerance by INTSORMIL and host country plant pathologists.

The 1993-94 cropping season was characterized by farmers having problems with poor stand establishment and severe drought. Farmers who had prepared their land early and planted at the proper time had average crops. Many farmers plowed and planted too late resulting in very poor stands. Research with seed dressings (fungicides plus insecticides) resulted in improved sorghum stands. Early plowing (first rain) combined with continued weed control until a December planting rain, resulted in increased sorghum yields.

Disease evaluations done at Pandamatenga, Botswana in early April 1994 indicated the presence of a virus disease similar to that observed in 1993. Red- and tan-leaf necrosis were the most common symptoms with only a minimal amount of viral mosaic observed. Reaction of sorghum entries from the International Sorghum Virus Nursery planted at this site were typical of MDMV-A or MDMV-B. Further evaluations are being conducted by DAR pathologists on virus specimens collected and transferred to the Sebele Station in Gaborone. MDMV-B is suspected because of its previous identification at the Mt. Makulu station in Zambia. In late March 1994, the incidence of MDMV-B and associated red- and tan-leaf necrosis (depending on host pigmentation) were quite heavy at Mt. Makulu in some released sorghum inbreds. In early April 1994, the drought response of sorghum in the Drought Line Test (DLT) and Preliminary Drought Line Test (PDLT) at two locations in Southern Zimbabwe (moderate to heavy drought stress at Matopos and early, heavy drought stress at Lucydale) indicated the necessity for pre-flowering drought tolerance in sorghum cultivars for this region. Sorghums primarily possessing post-flowering drought tolerance developed moderate to complete head blasting as stress increased in severity, especially if stress also occurred earlier in the season. Despite environmental stress and susceptible cultivars charcoal stalk rot was observed in only a few definitive instances.

Zimbabwe

The sorghum program has developed three early maturing seed parents from UNL-115 which initially was grown in Sebele. Selections from Botswana Serere 6A had also performed well in Namibia.

Male sterility in finger millet has been developed and is easily recognized. Seed set on unbagged male sterile heads shows 5-10% crossing which will occur with fertile plants in adjacent rows. This is sufficient for random mating and convenient for 'marking' sterile plants. Higher levels of seed can be obtained by deliberate pollination.

Screening of sorghum breeding materials found that lines having SC326-6 and SC120 in their background generally had better resistance to leaf blight than local and other improved cultivars.

Namibia

The national research focus is on breeding and agronomy of pearl millet. The national breeding program is comprehensive in its objectives, and David Andrews provides technical support to host country scientists. Agronomy and fertility experiments are in progress using cattle manure (kraaling overnight) and/or different levels of N and P fertilizers.

Zambia

Various plant disease problems were observed at Mansa, Mt. Makulu, and Golden Valley. At Mansa, anthracnose studies are being emphasized. At Mt. Makulu, viral necrosis ranged from 30-60% among the cultivars present. Severity of incidence ranged from minimal to 50% necrosis of leaves. At Golden Valley, sooty stripe destroyed 60% of the leaf tissue on susceptible cultivars. Research is being conducted on the use of seed treatment for control of sorghum downy mildew (SDM).

Senegal

Negotiations were continued with Oregon State University, the lead contractor in the new Senegal Natural Resources Based Agricultural Research Project (SNRBARP), on how INTSORMIL will be involved.

Kenya

Development of sorghum cultivars with tolerance to soil acidity is an environmentally friendly, relatively inexpensive, and permanent means of increasing sorghum yields on such soils. Cultural practices of resource-poor farmers without improved tolerant cultivars are labor intensive and because local types are used, low yielding. Acid soil tolerant varieties and hybrids, developed by INTSORMIL in Colombia, South America, perform well on acid soils in Kenya. Recent trials show that these tolerant sorghums are adapted to Western Kenya where soils are infertile and becoming increasingly acidified due to farming practices.

Five sources of *Striga* resistance, 11 lines with resistance to aphids, and 11 lines with drought resistance from Kenya were increased in Texas and crosses to elite photoperiod insensitive lines were made.

Honduras

Activities in the SRN/EAP/INTSORMIL program continued on schedule. Breeding plots have been planted in several locations.

Documentation was submitted to the Honduran National Seed Commission to release the downy mildew resistant sorghum-sudan forage hybrid (AT623*Tx2784). This hybrid has undergone extensive testing in Honduras since 1986 and is a significant step towards intensifying land use—a USAID mission objective. It has increased forage production by as much as 30% in some commercial operations. Some 70 on-farm demonstration plots had been distributed in 1993. It is important to note that INTSORMIL developed enhanced maicillo hybrids were the only sorghum cultivars that produced grain in the low rainfall area around Tapaire, Choluteca. Improvement of local landrace populations, such as development of maicillo hybrids, has been a long term objective of the INTSORMIL program in Honduras and this effort is now beginning to pay off.

Also, it was evident that small farmers had begun commercializing seed of enhanced maicillo varieties. For example, DMV179 was distributed to Miguel Gomez in 1990 at Las Espaveles. The following year, Miguel sold a portion of his harvest to Lorenzo Sell who took it to a World Neighbors community near San Ramón. A visit to the San Ramón area during a TAMU team visit revealed that a farmer had converted his field to DMV179—with about 10% mixture/outcrossing with local maicillo. In another part of Choluteca, a farmer had planted 5 ha of the enhanced maicillo variety DMV197. He was expecting yields of 50-57 t/ha from DMV197 whereas local landrace varieties were expected to yield 1.7-2.1 t/ha.

INTSORMIL collaborators at the EAP established a broomcorn variety test in Nicaragua near the Honduran border. Of the five varieties tested, Acme broomcorn performed the best. That particular farmer produces about 70 ha of broomcorn (on land rented from the Contras) and is eager to begin producing seed of Acme. He harvests about 180 kg/ha fiber on dryland and 450 kg/ha on irrigated production sites. Producing broomcorn and making brooms has become a cottage industry in Nicaragua. Fields of broomcorn and selling round brooms on the roadside is a frequent sight as one travels from the border to Managua in Nicaragua.

Plans for the 1994 cropping season are in progress. This will be the first cropping season without an INTSORMIL long-term expatriate stationed in Honduras. Plans are for the research program to continue in the same manner as before with the same locations and nurseries. Increased involvement in regional activities is anticipated during 1994. The program is orienting toward a more collaborative mode involving host country and U.S. scientists.

Henry Pitre, MSU-105 PI, continued his collaborative research on entomology in Honduras.

Metaponpneumata rogenhoferi (Moschler) (Lepidoptera: Noctuidae) is one of four insect species in a complex of lepidopterous defoliators, locally referred to as "langosta", limiting production of intercropped sorghum and maize in Honduras. The limited time of occurrence of this very destructive species in this region was investigated in relation to diapause behavior. The influence of age of pupae and soil moisture on diapause was measured in the laboratory (90°). Pupae collected in the field were exposed to different levels of soil moisture at intervals after pupation. Adults emerged (ca. 20%) from pupae exposed at intervals from August through October; emergence decreased to 5-7% for pupae exposed for the first time after October. Soil moisture level, however, did not appear to be closely associated with termination of diapause, but time in diapause appeared to have some effect. Information on diapause behavior of this species and other species in the "langosta" pest complex will further our ability to use insect behavior in developing insect pest management practices for specific crop production regions.

Colombia

Collaborative Program

This is a terminal report for the INTSORMIL Colombian Prime Site. This Prime Site was terminated and INTSORMIL activities merged with the Honduran Prime Site on June 30, 1994 by INTSORMIL, primarily because of USAID travel restrictions to Colombia. This report will summarize the Colombian Prime Site's activities and productivity since its inception.

Program Implementation

This collaborative research project operated in Colombia under four formal and several informal agreements which facilitated the project's involvement in a broad range of research activities. In 1981, a Memorandum of Intention was signed by the Directors of INTSORMIL, ICRISAT, and CIAT. Research started in 1982 through informal cooperation among ICA, EMBRAPA, and INTSORMIL. Sorghum and millet research was formalized with the Colombian government in 1988 through a Memorandum of Agreement among ICA, INTSORMIL, and CIAT.

Through a 1988 INTSORMIL buy-in, research was initiated in the acid savannas of Arauca by means of a Memorandum of Agreement between INTSORMIL and the El Alcaraván Foundation, a consortium of petroleum companies (Shell, Ecopetrol, and Occidental de Colombia), managed by Occidental. Informal agreements and close links have been established with nonprofit organizations such as FENALCE, a Colombian production and extension-oriented organization, and three Colombian universities. Since 1990, formal and informal agreements in different research areas were made with seed companies that have research programs in Colombia, such as CIBA-Geigy and FEDEARROZ.

The INTSORMIL collaborative research project, MSU-111, was managed by the Office of International Programs, Mississippi State University.

Interdisciplinary Research

This Prime Site was originally established to conduct breeding research on problems relating to acid soil production constraints of sorghum and pearl millet. The research was initiated in 1982 by Dr. Lynn M. Gourley, MSU-104 PI. Plant breeders at all INTSORMIL institutions have had germplasm evaluated at this site through germplasm exchange. Specific long-range research goals in Colombia had included breeding for acid soil tolerance (MSU-104), pearl millet (UNL-118 and KSU-101), drought tolerance (TAM-122), pathology (TAM-124), and grain quality (TAM-126 and PRF-103B) investigations. Some entomology input was provided by MSU-105.

The MSU-111 project (also terminated on June 30, 1994) operated from CIAT, near Palmira in the Cauca Valley, where multinational seed companies have most of their experiment stations. Through CIAT infrastructure, the project had established linkages with most public and private research programs, and NARS of other Latin American countries.

The major center for seed increase and distribution was at CIAT, Palmira. In contrast, breeding activities took place at different sites in the Colombian Eastern Plains (Llanos Orientales), where soils with different levels of Al saturation are found in both well-drained and poorly drained savannas. The project used ICA's experiment farms, or land rented from either CIAT or private farmers to obtain a range of ecosystems for each level of Al saturation. At ICA-La Libertad (near Villavicencio, Department of Meta), scientists from ICA, FENALCE, and INTSORMIL collaborated in agronomic and breeding research, according to established objectives.

Because of the diversity of collaborating institutions, the project conducted more than just acid soil tolerance breeding research. For example, FENALCE developed lines for semiarid areas (TAM-122) and lines resistant to grain molds. ICA developed drought-tolerant lines, adapted to acid soils and resistant to grain molds (TAM-124). The universities conducted research in agronomy and physiology (UNL-114), and entomology (TAM-125 and MSU-105). The El Alcaraván Foundation developed germplasm adapted to acid savannas and slightly acid soils (vegas). The Foundation was also interested in grain quality and utilization (TAM-126 and PRF-103B). Most of these research activities were conducted by scientists from ICA or the private sector, supported by undergraduate students working on their B.Sc. theses.

Collaboration with Other Organizations

International Centers

The selection of the International Center, CIAT, as the operational headquarters for the Colombian Prime Site research was ideal. The student training program and CIAT's outreach programs throughout Latin America kept INTSORMIL's sorghum and millet research very visible. Collaboration with ICRISAT Center and ICRISAT's outreach programs in Mexico (CIMMYT) and SADC in Zimbabwe contributed to the success of this project. At the time the INTSORMIL program in Colombia was terminated, CIAT, ICRISAT and INTSORMIL were attempting to get funding from the Latin American Bank for a joint acid soil research project.

Since 1982, CIAT and ICRISAT have supported International Workshops in Colombia concerning sorghum and millet research. In 1984, CIAT provided facilities and other support for the Workshop "Evaluating Sorghum for Tolerance to Al-Toxic Tropical Soils in Latin America" and in

1991 for the Workshop "Sorghum for the Future." CIAT has supported the project in several other ways: administratively, CIAT staff time, and opening alternatives for new research areas. Land, laboratories, equipment, and transport are only some of the facilities that CIAT has made available to the project. CIAT also increases breeders' seed of INTSORMIL lines for release in Colombia.

Private Sector

INTSORMIL has always collaborated closely with the private sector, which includes national as well as multinational entities headquartered in Colombia. Since 1982, many private companies have sent lines from the world collection for evaluation of acid-soil tolerance under different Latin American conditions. Although many lines were identified as Al-tolerant and used as progenitors for developing genotypes adapted to tropical conditions, a major problem was excessive plant height of more than 200 cm of their F1 progeny. Most Latin American countries prefer short hybrids. Collaboration with the private sector has increased the possibility of finding hybrids adapted to the stresses predominant in Latin America's acid soil regions.

Most Latin American countries are privatizing and opening their economies to outside trade. The NARS involved in the sorghum and millet research have also been part of this process. In Colombia and Peru, future public research will become the responsibility of private or joint venture companies.

In Colombia, FENALCE stations an agronomist (B.Sc.) in each sorghum-growing region to provide farmers with technical support. ICA provides farms and scientists for all projects involving both institutions. The El Alcaraván Foundation fully supported research in Arauca under INTSORMIL's leadership.

Planning Collaborative Research

From the beginning, a close working relationship was established with CIAT, facilitating research and promoting linkages with both foreign and national entities. ICA was INTSORMIL's principal scientific collaborator. The PI assigned to Colombia and the ICA scientist assigned to ICA's sorghum program at La Libertad met annually to establish work plans.

Since 1988, relations among the institutions involved in Colombian sorghum research became complex, requiring careful coordination of research activities. Specific short- and long-term goals were developed jointly with INTSORMIL Projects MSU-111 and MSU-104, ICA, El Alcaraván, FENALCE, and the Colombian universities. Formal planning meetings were held annually to discuss specific experiments, organizational funding, and individual responsibilities. Results were published annually, and distributed among those involved.

Sorghum/Millet Constraints Researched

The main overall constraint to sorghum production in Latin America is the high cost of production. Most sorghum has been grown on high value land, making production of this crop a nonprofitable enterprise. One method of reducing production costs was incorporating marginal lands into the production system. This low-value land has production constraints including the poor distribution of water, soil acidity, and high Al saturation, presence of pests and diseases, periods of excessive rainfall with high relative humidity, and other related agronomic problems. Thus, sorghum production in these areas required the development of varieties or hybrids adapted to the specific ecological problems prevalent in each region.

In spite of the constraints encountered in these marginal areas, the amount of land available is such that the acid, well-watered savannas of Latin America constitute the main potential region for sorghum production. Acid, infertile soil savannas account for more than 10% of the land area in Latin America and the Caribbean. Some 76 million hectares of well-watered savannas are currently available for more intensive cultivation in the future in Colombia alone. Farmers throughout the region require low-input technology and research information to avoid resource degradation problems; thus, work to develop sustainable agricultural systems becomes a mandate.

Research Progress

Research progress was excellent until the Colombian Prime Site was discontinued. Due to travel restrictions, this country program was the smallest within INTSORMIL in terms of number of PIs involved. Since MSU-111 and MSU-104 were both breeding projects, INTSORMIL's involvement was primarily breeding while ICA's role was more in other disciplines and included some extension activities.

ICA and the El Alcaravan Foundation, with INTSORMIL's support, released two acid soil tolerant sorghum cultivars in 1993 which are adapted to growing conditions in Arauca in the Colombian Eastern Plains. The cultivars have been named Icaravan 1 (IS 3071) and Icaravan 2 (IS 8577). Icaravan 1 is exceptionally hardy and has produced more than 3 t ha^{-1} grain under low fertilization levels and when the Al-saturation level is 60% or less. It also tolerates partial flooding after flowering - an essential characteristic in poorly drained savannas. Icaravan 2 is very tolerant to Al toxicity and has good agronomic characteristics when grown under Arauca's soil and climatic conditions.

FEDEARROZ and ICA announced the release of a hybrid for the dry Caribbean region of Colombia, which uses an A-line from the INTSORMIL MSU-104 project and an R-line from Texas A&M University. Hybrids using one or both parental lines developed in Colombia are currently being evaluated in many countries with acid and/or infertile soils. Since 1990, experimental sorghum hybrids using lines developed in Colombia have been evaluated in east Africa. The bird resistant germplasm being developed by the INTSORMIL Colombian program is similar to that used throughout many areas in Colombia and in western Kenya and throughout Uganda is used for food. Several of these hybrid combinations are in the final stages of evaluation before being released to farmers.

Egypt

The Egypt/INTSORMIL program consists of research efforts within two groups in the Agricultural Research Center (ARC). The plant pathology research group in the MSSCFC Section of the Plant Pathology Institute and the sorghum research section of the Field Crops Research Institute of ARC.

Plant Pathology

Dr. Thanaa Fahmy Ibrahim, Dr. Tawfic Abdel-Moity and Mr. Abu-Serie Ismael participated in short-term training in the Plant Pathology Department of Kansas State University during the spring semester of 1994. Dr. Ibrahim focused on classical microbiology of bacterial pathogens of sorghum. Dr. Abdel-Moity studied parameters that are involved in the use of nontoxin-producing *Fusarium* species as biological controls in sorghum. Mr. Abu-Serie Ismael conducted experiments with SDS polyacrylamide gel and agarose gel electrophoresis of proteins and DNA to determine differences between Egyptian and U.S. isolates of *Pseudomonas andropogonis*. These data were to be incorporated into Mr. Ismael's Ph.D. thesis.

Work focused on the characterization of *Fusarium* populations from Egypt and comparing these populations with those from other locations. Egyptian *Fusarium* populations from sorghum appear to be dominated by members of the D mating population *(Fusarium proliferatum)* instead of the F mating population *(Fusarium proliferatum)* as is common in the United States and Tanzania. The reasons for this difference in population composition are unknown. Members of the D mating population are known to make gibberellic acid and may be responsible for the pokkah boeng disease symptoms that we have commonly observed on Egyptian sorghum. Some members of the D mating population are known to synthesize moniliformin and fumonisin mycotoxins, and, thus, may pose a hazard to humans and animals that consume sorghum grain and/or sorghum forage.

Sorghum Agronomy

Production experiments have dealt with the effects of different water and nitrogen levels and the water x nitrogen level interactions in order to optimize water use efficiency (WUE) and nutrient use efficiency (NUE). Water and N level effects at modest input levels are almost additive. Experimentation approach and set ups are now geared up and need several years operation in a range of the "New Lands" marginal areas to come up with the best guidelines to stretch Nile water supplies and minimize N imports. Drs. Bashir and Kamal have a good start on this. Nubaria needs to be developed along with irrigation equipment for other sites.

Sorghum breeding faces challenges to tailor germplasm to the expanding marginal land areas and boost production. A good percentage of the germplasm used there is like Giza 15 and some locals which fit their conditions quite well in the traditional sorghum areas. The germplasm base related to these is probably fairly narrow and breeders are involved in widening the base. One hopefully useful approach was started last year by applying pollen from Giza 15 and many locals to sterile heads in a Nebraska midseason stress resistant tan plant population to develop a new Egypt adapted randomly mating population. Such a population should provide an easy means to incorporate new germplasm sources into a breeder working pool to be used in conjunction with conventional breeding approaches.

United States

The EEP INTSORMIL project reviews of the Texas program took place at Corpus Christi, July 12-13, College Station, July 14-15, and Lubbock, September 20-21, 1993. The EEP also reviewed the Nebraska, Kansas, and Purdue Programs in September. Excessive moisture and unusual low temperatures delayed crop development at these sites.

Research is being continued on evaluating increasing the seed size component of yield in sorghum as it may relate to (1) post anthesis stress resistance, (2) higher yields under relatively optimal conditions, (3) higher water use efficiency under stress and favorable conditions, (4) housewife preference in developing countries and (5) value added for livestock feeders through cheaper processing and greater starch release. Increasing seed size without decreasing yield (decreasing seed number) depends partly on increasing grain fill length which relates to metabolic pace. Metabolic pace is being estimated by measuring grain respiration rate in the field with a portable analyzer in a nondestructive manner. Seed saved is then used for genetic manipulation which is being supported through INTSORMIL and a Nebraska Grain Sorghum Board leveraging grant.

In Texas, excellent disease, insect, drought, and adaptation sorghum nurseries were obtained this year. High rainfall contributed to high disease pressure in South Texas. A very long and continuous drought in West Texas resulted in excellent drought nurseries (both pre-and post flowering stress nurseries) in the Lubbock area.

Plots planted at Lubbock for the purpose of identifying nitrogen efficient breeding lines are in the process of being harvested. A chlorophyll meter is being investigated for use as a possible screening tool to determine nitrogen status of sorghum at various growth stages. It is also being investigated as a potential indicator of nitrogen use efficiency.

In Texas, two students supported by INTSORMIL and their major professors are measuring the control capability of natural enemies of aphids infesting grain sorghum. During the summer of 1993, they researched removal of these natural enemies from large plots of grain sorghum with the short term goal of distinguishing the mortality caused by the respective species of natural enemies. The primary objective of this work is to provide methodology and information on how to use these natural enemies more effectively in integrated pest management programs.

Darrell Rosenow and Gary Peterson traveled to China in August on a UNDP program. They evaluated sorghum research nurseries at the Sorghum Research Institute, Liaoning Academy of Agricultural Sciences in Shenyang. This travel provided information on some potentially important new germplasm from China which should be useful to INTSORMIL researchers.

Germplasm Improvement

In Nebraska, the threat of early frost hastened seed harvest. Harvest of grain yield trials proceeded well after a season of exceptionally high rainfall. Winter nursery seed was put up and dispatched. Germplasm population NPM-3 was released. This is the first public source of material available in a dwarf early maturing background that will restore male-fertility on the A_4 (monodii) cytoplasmic male-sterile system. This restorer source will now permit this new system, which has several significant advantages, to be used in making grain hybrids. The seed set on new A_4 hybrids test in 1993 was generally superior to seed set on A_1 hybrids.

David J. Andrews, PI for projects UNL-115 and 118, was awarded the International Service in Crop Science Award at the November ASA annual meeting in Cincinnati. The International Service in Crop Science Award recognizes outstanding achievement in the international area of crop science. The focus of the award is on creativity and innovation in bringing about specific changes in practices, products, and/or programs in the crops area at the international level.

In Texas, progress continued in sorghum breeding for high stable yield and resistance to stresses. One major dominant gene and one major recessive gene, controlled the ability of sorghum to stay green under drought. A consistent relationship has been shown between high nonstructural carbohydrates in the stem and charcoal rot resistance. Two-gene systems appear to control relative water content, osmotic potential, and heat tolerance. Eight genes have been described which affect food quality of the grain. Field selections were made in south Texas for adaptation to tropical environments, disease resistance, and grain quality. F_2 populations were increased which will be used to provide materials to collaborators in Mexico, Honduras, Mali, Sudan, Kenya, and Southern Africa.

At Purdue, transgenic sorghum plants have been obtained after microprojectile bombardment of immature embryos (PRF-103A). The protocol for obtaining transgenic plants consists of the delivery of the bar gene to immature embryos and the imposition of biolaphos selection pressure at various stages during culture from induction of embryogenesis to rooting of regenerated plantlets. The presence of the *bar* and *uid*A genes was confirmed by PCR and Southern blot analysis of plant genomic DNA. Phosphinothricin acetyltransferase activity was detected in extracts of the regenerated plants and these plants were resistant to local application of the herbicide Ignite/Basta. T1 seedlings are now being evaluated. A similar protocol has been used to obtain putative transformed calli from immature inflorescences, and regenerate plants that are being tested for the presence and expression of the *bar* gene.

Sustainable Production Systems

Extensive developmental physiology research in the 70's and 80's was used to fashion a preanthesis stress screening field method. Preanthesis stress is a problem in many tropical countries as well as being the major stress period most years in temperate climates. The physiological research clearly illustrated (scanning electron micrographs) that microsporogenesis and megasporogenesis are major stress sensitive stages. Tapetal damage caused nutritional problems which lead to microspore damage during microsporogenesis. Similar translocation (nutritional) problems caused ovule abortion.

Pinpointing the developmental time of damage allowed timing stress in the field to select stable, high seed number stress-resistant (preanthesis) genotypes. Our stress screening model was tested and validated by selecting good yielding S_1 plants from a randomly mated tan plant sorghum population which were advanced to the S_3 generation, selected for stress resistance in the field using our methodology and recombined to form a new stress resistant population. The population has been or is being used in Niger, Senegal, Sudan, Mexico and Egypt. Population selections in hybrid combination are competitive with commercial hybrids and usually exceed them in stress tests.

Current research (UNL-116, Jerry Eastin) is centered on increasing seed size potential as a post anthesis stress yield compensating mechanism. Increased seed size also relates to increasing yield potential under good conditions. In addition, the developing country housewife normally prefers larger seed sizes in the marketplace. Also, livestock feeders in the U.S. prefer larger seed sorghums to decrease roller milling energy costs and improve kernel fracture to release more readily digestible starch as in perceived in the treatment and use of maize as a livestock feed. These investigations are being heavily coordinated with germplasm improvement programs by Egyptian plant breeders. A big advantage in Egypt is total water control to get good plant anthesis stress control not readily achieved in the U.S.

Experiments comparing improved Malian sorghums against U.S. types at the University of Nebraska (Ph.D. dissertation study) at low and high soil N levels showed that both Malisor 7 and S-34 ranked among the highest for NUE among 15 genotypes. A genotype by nitrogen level interaction occurred at the boot and flowering growth stages but not at maturity. Seed quality and poor stands were also a problem with the Malian types.

Irrigated experiments conducted on sorghums specifically selected for high NUE at Kansas State University and the University of Nebraska for agronomic response to N application (M.S. thesis) showed that the hybrids responded much better to N application than the high NUE parent lines as would be expected. The best hybrid at 0 kg N ha^{-1} application was Tx623/SC566, (3449 kg ha^{-1}) and the best at 100 kg N ha^{-1} was TX623/IR204 (5537 kg ha^{-1}). High NUE lines varied in their response to N, but were all responsive (UNL-114, Jerry Maranville).

Sustainable Plant Protection Systems

During the period of January 1-March 31, 1994, Richard Frederiksen (TAM-124) was able to select several DNA probes from a genomic library of *Collectotrichum graminicola* that will be used in evaluation of the population dynamics of this pathogen. Progress has been made on the laboratory identification of compatible isolates of *Sporisorium reilianum*, the fungus causing head smut of sorghum. This technique may permit the rapid identification of virulent isolates and be useful in defining some of the factors contributing to pathogenicity in the fungus. They put together a collection of 198 commercial sorghum hybrids for obtaining data sets on reactions of these hybrids to the most important diseases of sorghum. These data will be integrated into an interactive computer model for use in developing integrated sorghum production systems. Integrated production systems are the most environmentally safe and sustainable systems for both developed and developing agriculture. Sorghum disease nurseries in south Texas were planted as a part of the continuing research programs. Dr. Melville Thomas spent the academic year at Texas A&M using techniques in biotechnology as they apply to characterizing populations of *Colletotrichum graminicola*. Mr. Issoufou Kollo has begun the application process to begin graduate work at Texas A&M; however, his application has not been completed and he may not be able to begin until Spring Semester, 1995.

Crop Utilization

Purdue has two new graduate students working on the INTSORMIL project - Adam Aboubacar (Ph.D.) from Niger who is funded from the project and Charlotte Weaver (M.S.) who is funded from an outside source. A third project-funded student is in her last year of her Ph.D. studies.

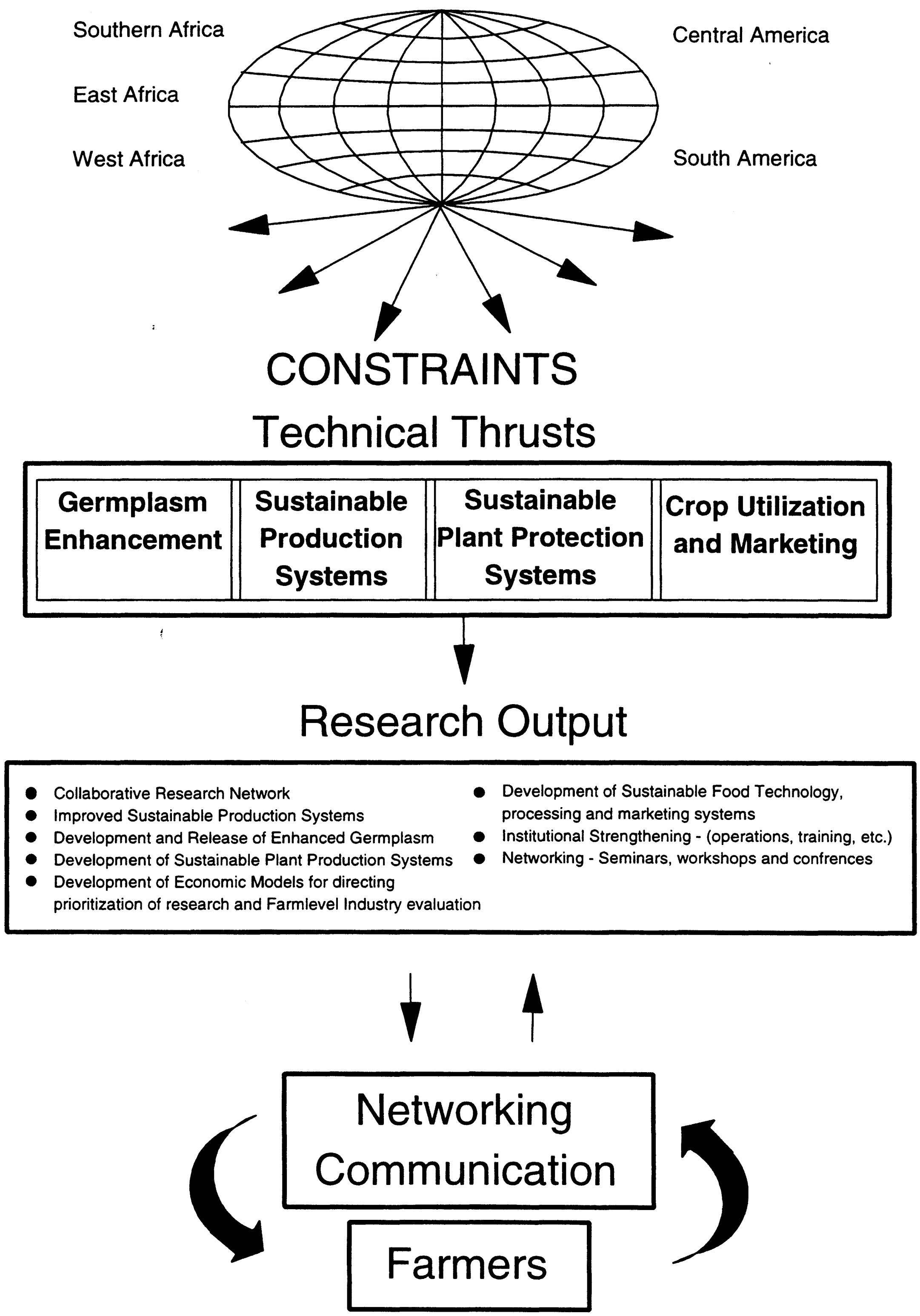
The most significant finding of late concerns the poor protein digestibility of sorghum. In screening 25 selected sorghum genotypes for *in vitro* protein digestibility they found a range from 66 to 88% for uncooked values and 48 to 81% for cooked values. Two sorghum lines had notably higher digestibilities compared to the other sorghums tested. Perhaps more important, digestibility of these two sorghums did not decrease appreciably on cooking which is commonly seen with sorghum. This was verified using two *in vitro* enzyme systems. Chemical studies showed that in the two highly digestible sorghums the major storage protein (about 65% of total protein), α-kafirin, was digested much earlier than the other sorghum samples. Also, a group of high molecular weight proteins, that usually restrict the digestion of α-kafirin, was digested very rapidly. This group of sorghums is now being grown in Mexico to determine if this is a heritable trait. If this proves to be so, we believe that a rapid screening assay for digestibility can be developed based on chemical differences between genotypes.

Adam Aboubacar has set up a laboratory-scale process to make couscous and is examining physical and chemical properties of various sorghum and millet types in relation to their couscous-making ability. He is trying to better understand the controlling factors in the grains that are necessary to produce a couscous product competitive to wheat couscous.

Future Directions

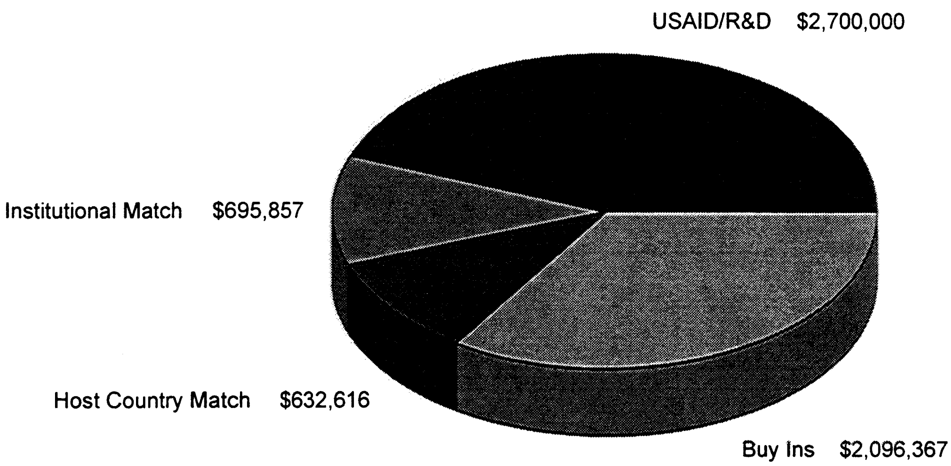
INTSORMIL will continue to jointly plan and execute collaborative research that benefits developing countries and the United States. These collaborative relationships are keys to INTSORMIL's success and will continue as fundamental approaches to meeting the INTSORMIL mission. In the future, INTSORMIL will target NARS collaborative ties that reflect regional needs for sorghum and/or millet production. These ties are envisioned to be in the sorghum and millet agroecological zones of western, eastern, and southern Africa, and Central America. By concentrating collaboration in selected sites, INTSORMIL optimizes its resources, builds a finite scientific capability on sorghum and millet, and creates technological and human capital that has a sustainable and global impact. INTSORMIL will use four specific strategies to maintain its current momentum, build on its record of success, and accomplish a new set of goals. These strategies are (1) sustainable research institutions and human capital development, (2) conservation of biodiversity and natural resources, (3) research systems development with focus on relevant technology generation, and (4) information and research networking.

INTSORMIL GLOBAL PLAN

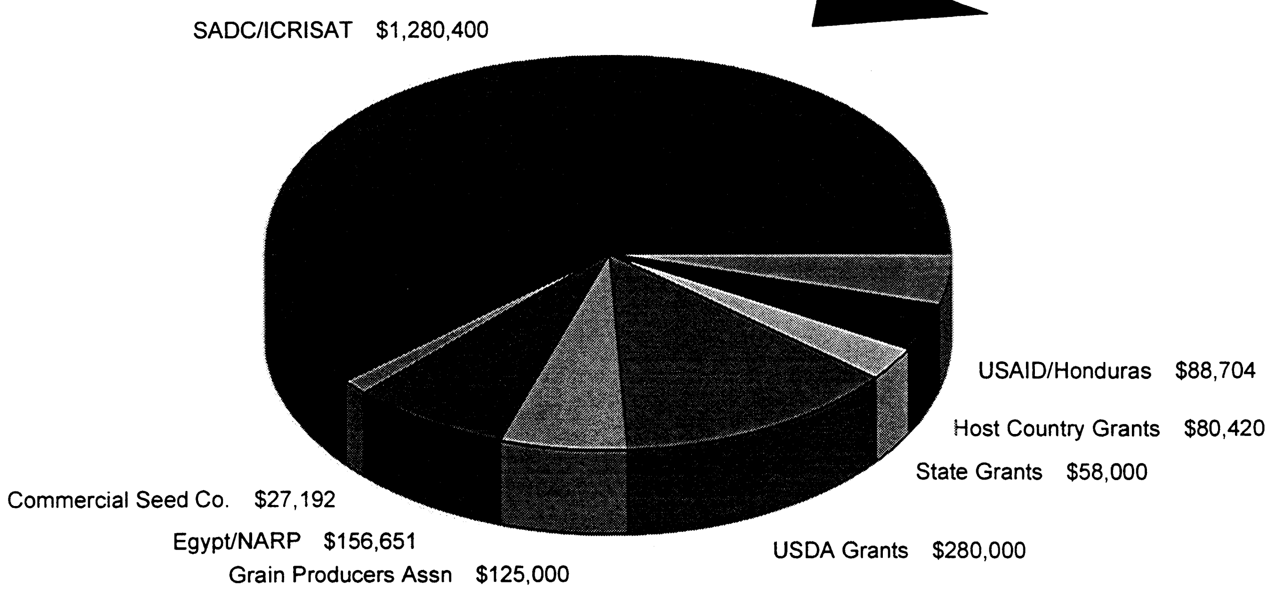


INTSORMIL Source of Funding

Total Year 15 - $ 6,124,840

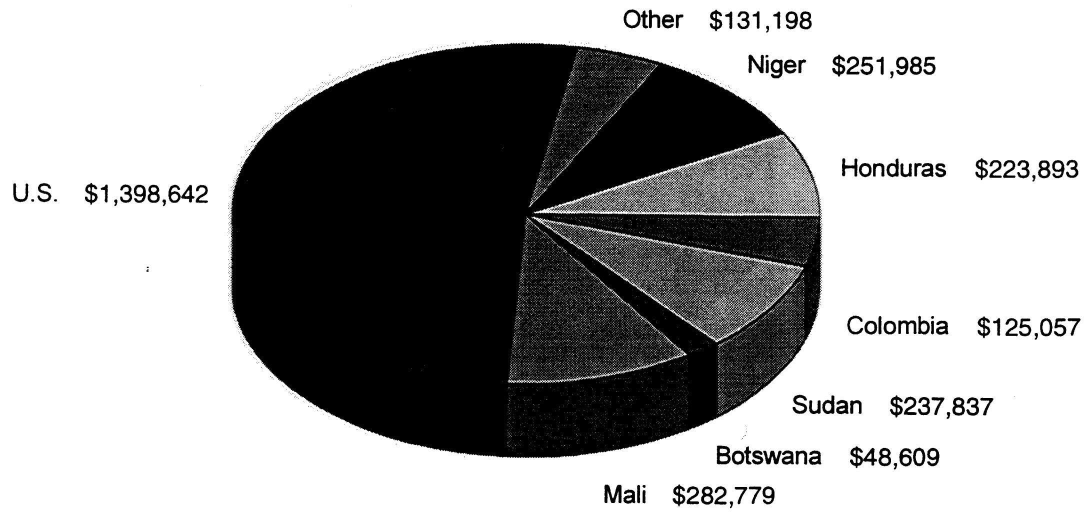


Total Source Breakdown

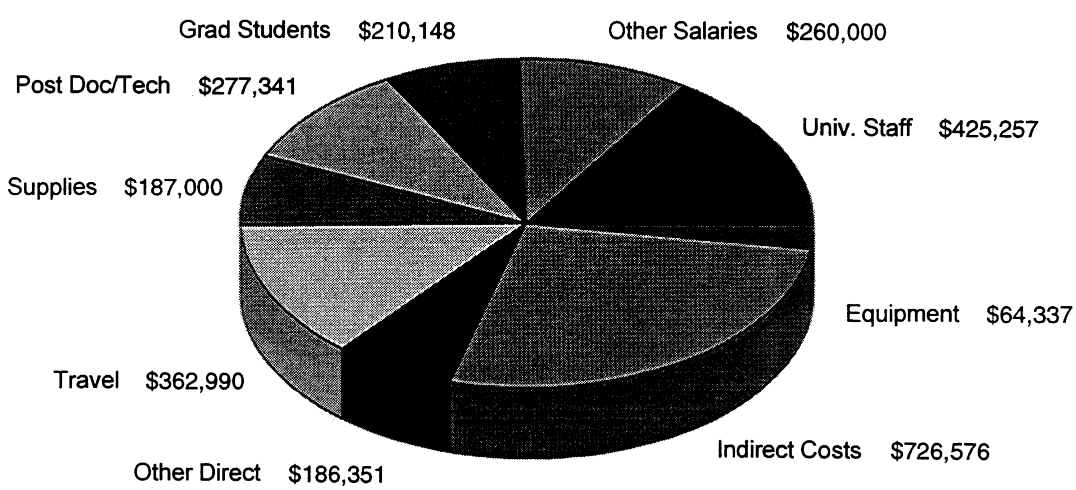


Buyin Breakdown

Year 15 - FY 94
INTSORMIL Budget Analysis
Functional - $2,700,000

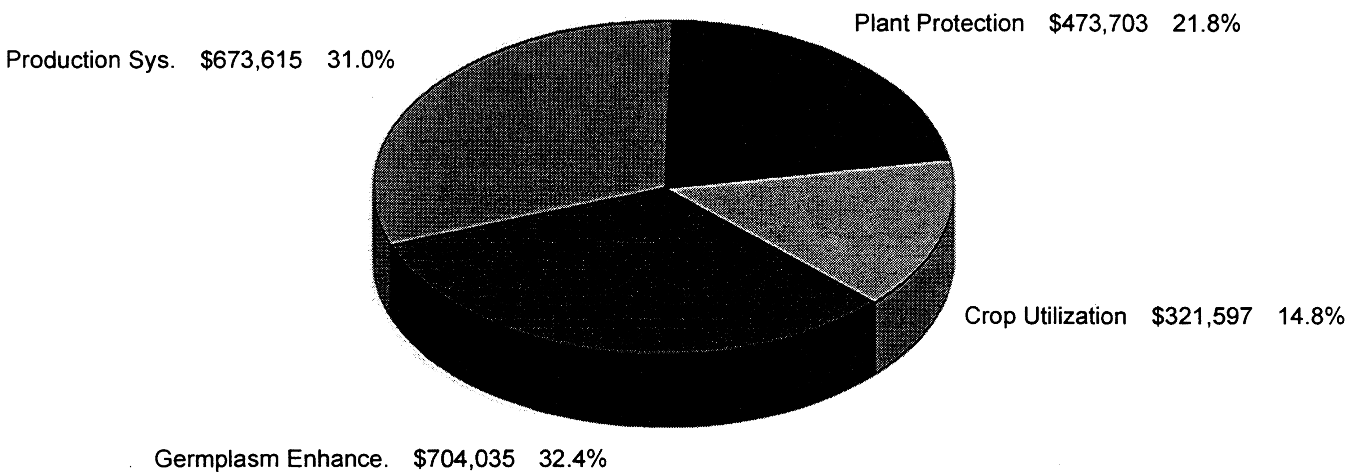


By Country

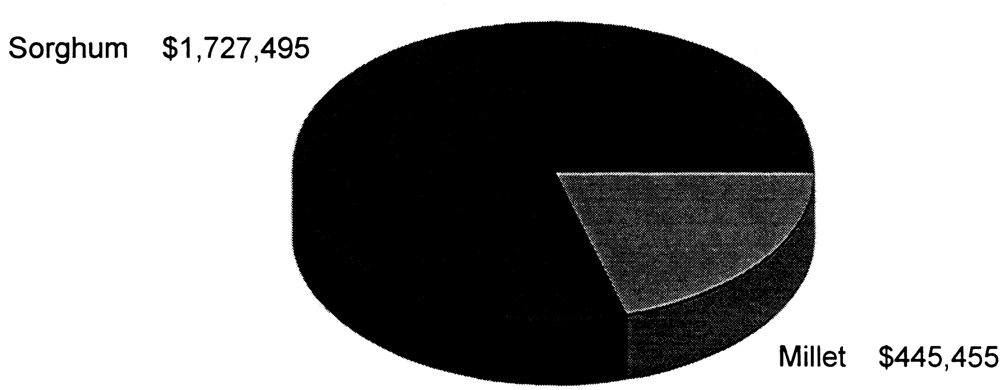


By Line Item

INTSORMIL FY 94 Budget Analysis
Technical - $ 2,172,950



By Technical Thrusts



By Crop

Table 1. USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY80) through 15 (FY94) for all Collaborative Research and Management Entity.

Budget Line Items	FY 80-85 Years 1-6	FY 86-90 Years 7-11	FY 91-93 Year 12-14	FY 94 Year 15	FY 80-94 Totals
Salaries & Benefits	$ 7,604,987	$ 6,237,598	$ 3,794,675	1,145,746	$ 18,783,006
Equipment & Facilities	1,292,255	634,996	212,105	42,337	2,181,693
Travel	1,862,258	1,572,005	879,282	333,990	4,647,535
Other Direct Costs	1,018,921	1,518,436	1,292,384	346,351	4,176,092
Technical Assistance	341,290	57,000	20,000	5,000	423,290
LDC Special Projects	2,160,955	1,357,725	524,906	100,000	4,143,586
Indirect Costs	3,869,334	3,353,940	2,146,648	726,576	10,096,498
Total	$ 18,150,000	$ 14,731,700	$ 8,870,000	$ 2,700,000	$ 44,451,700

Table 2. USAID-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research, U.S. Institutions (Florida A&M University, University of Arizona, Kansas State University, University of Kentucky, Mississippi State University, University of Nebraska, Purdue University, Texas A&M University), and the Management Entity.

Budget Line Items	FL	AZ	KY	KS	MS	NE	PR	TX	Institutional Total	ME Budget	ME TA-LDC	Total Grant
Years 1 - 6 (FY 80-85) A.I.D. Grant - AID/DSAN/XII-G-0149												
Salary & Benefits	85,270	191,675	287,013	896,270	828,186	1,622,402	1,224,363	1,833,520	6,968,699	636,288		7,604,987
Equipment & Facilities	35,500	41,529	4,600	134,655	34,968	159,889	129,863	726,750	1,267,754	24,501		1,292,255
Travel	14,500	27,523	136,390	276,950	177,094	233,533	216,753	435,559	1,518,302	343,956		1,862,258
Other Direct Costs	7,500	5,670	55,271	142,027	112,537	148,359	217,751	242,370	931,485	87,436		1,018,921
Technical Assistance											341.290	341,290
LDC											2,160,955	2,160,955
Indirect Costs	35,106	58,283	165,476	397,575	447,465	762,315	661,080	894,215	3,421,515	447,819		3,869,334
TOTALS	$ 177,876	$ 324,680	$ 648,750	$ 1,847,477	$ 1,600,250	$ 2,926,498	$ 2,449,810	$ 4,132,414	$ 14,107,755	$ 1,540,000	$ 2,502,245	$ 18,150,000
Years 7 - 11 (FY 86-90) A.I.D. Grant - AID/DAN-1254-G-SS-5065-00												
Salary & Benefits			100,954	754,097	532,584	1,044,184	1,324,037	1,718,681	5,474,537	763,061		6,237,598
Equipment & Facilities			800	90,817	79,347	170,837	95,802	185,210	622,813	12,183		634,996
Travel			27,684	165,613	131,996	199,309	353,523	405,880	1,284,005	288,000		1,572,005
Other Direct Costs			17,213	116,960	148,757	202,525	366,378	483,008	1,334,841	161,595	22,000	1,518,436
Technical Assistance											57,000	57,000
LDC											1,265,525	1,265,525
Discontinued Projects and Grad Student Support											92,200	92,200
Indirect Costs			54,999	319,538	265,566	544,370	811,010	901,296	2,896,779	457,161		3,353,940
TOTALS			$ 201,650	$ 1,447,025	$ 1,158,250	$ 2,161,225	$ 2,950,750	$ 3,694,075	$ 11,612,975	$ 1,682,000	$ 1,436,725	$ 14,731,700
Years 12 - 15 (FY 91-94) USAID Grant - AID/DAN-1254-G-00-0021-00												
Salary & Benefits				410,932	495,411	756,237	1,030,042	1,381,749	4,074,371	843,050		4,917,421
Equipment & Facilities				19,138	9,411	77,378	35,300	80,215	221,442	6,500		227,942
Travel				59,388	90,535	143,644	250,689	404,516	948,772	240,500		1,189,272
Other Direct Costs				88,734	115,136	204,767	666,058	412,800	1,487,495	124,740		1,612,235
Technical Assistance											121,800	121,800
LDC/Special Projects*											628,106	628,106
Indirect Costs				198,358	222,157	380,424	763,511	853,320	2,417,770	455,454		2,873,224
TOTALS				$ 776,550	$ 932,650	$ 1,562,450	$ 2,745,600	$ 3,132,600	$ 9,149,850	$ 1,670,244	$ 749,906	$ 11,570,000
Year 16 (FY95) USAID Grant - AID/DAN-1254-G-00-0021-00 (July 1, 1994 - June 30, 1995)												
Salary & Benefits				42,940	36,035	139,424	247,483	267,011	732,893	201,400		934,293
Equipment & Facilities				2,300	2,683	14,358	4,500	42,252	66,093	1,850		67,943
Travel				17,184	16,500	18,500	50,700	100,524	203,408	45,000		248,408
Other Direct Costs				8,732	44,612	25,629	120,995	65,894	265,862	34,000		299,862
Technical Assistance											25,000	25,000
LDC Special Projects*											120,400	120,400
Indirect Cost				28,844	30,170	74,389	168,222	184,719	486,344	117,750		604,094
TOTALS				$ 100,000	$ 130,000	$ 272,300	$ 591,900	$ 660,400	$ 1,754,600	$ 400,000	$ 145,400	$ 2,300,000
GRAND TOTALS	$ 177,876	$ 324,680	$ 850,400	$ 4,171,052	$ 3,821,150	$ 6,922,473	$ 8,738,060	$ 11,619,489	$ 36,625,180	$ 5,292,244	$ 4,834,276	$ 46,751,700

*LDC and Special Projects/External Evaluation Panel, Mali/Niger Country Projects

Table 3. Management Entity Office Budget Details.

Budget Line Items	FY 80-85 Years 1-6	FY 86-90 Years 7-11	FY 91-93 Years 12-14		FY 94 Year 15	Totals FY 80-94 Years 1-15
Salaries & Benefits	$ 636,288	$ 763,061	$ 650,500		188,550	$ 2,238,399
Equipment & Facilities	24,501	12,183	4,850		1,650	43,184
Travel	339,956	257,000	110,500		45,000	752,456
International				10,000		
Domestic				5,100		
Board of Directors				4,300		
Technical Committee				11,800		
Ecogeographic Zone Committee				13,800		
Consultants	6,600	22,000	12,000		4,000	44,600
Other Direct Costs	84,836	144,595	77,740		35,000	342,171
Indirect Costs	447,819	457,161	317,604		137,850	1,360,434
Total	$ 1,540,000	$ 1,656,000	$ 1,173,194		412,050	$ 4,781,244
P.I. Conference		16,000	25,000			41,000
External Evaluation Panel		10,000	95,000		75,000	180,000
Special Projects			113,000		10,000	123,000
ME Total Costs	$ 1,540,000	1,682,000	$ 1,406,194		$ 497,050	$ 5,125,244

Table 4. Sorghum/Millet CRSP Summary of Non-Federal Matching Contributions by U.S. Institutions - Grant Years 1 (FY 80) through 15 (FY 94).

U.S. Institution	FY 80-93 Years (1-14)	FY 94 Year 15	FY 80-94 Totals
University of Arizona	$ 149,310	$	$ 149,310
Florida A&M University	23,898		23,898
University of Kentucky	215,649		215,649
Kansas State University	1,606,001	84,022	1,690,023
Mississippi State University	828,619	45,000	873,619
University of Nebraska	1,871,316	114,656	1,985,972
Purdue University	2,165,585	167,757	2,333,342
Texas A&M University	3,607,651	284,422	3,892,073
Total	$ 10,468,029	$ 695,857	$ 11,163,886

TRAINING

INTSORMIL gives high priority to training host country scientists who will have major responsibilities for sorghum and millet research in their home countries. Training is also provided for young U.S. scientists who plan for careers in overseas development work.

The most frequently used mode of training is graduate study for advanced degrees, with the students' research forming an integral part of an INTSORMIL project. During the year covered by this report, 96 students from 33 different countries were enrolled in an INTSORMIL advanced degree program. Approximately 78% of these students come from countries other than the U.S. which shows the emphasis placed on host country institutional development (Figure 1).

Figure 1. Training analysis - country breakdown.

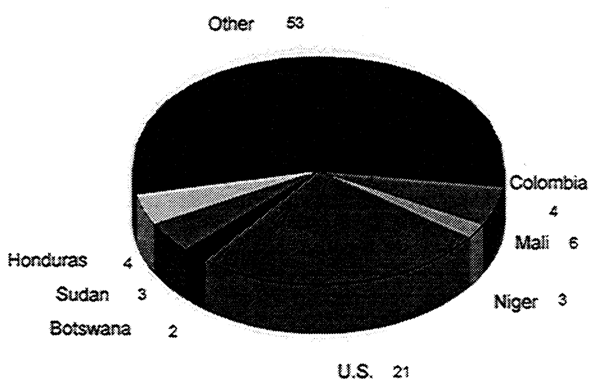
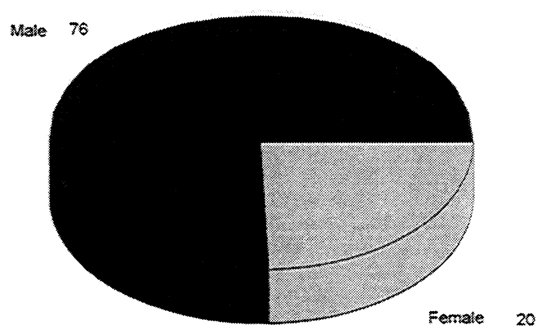
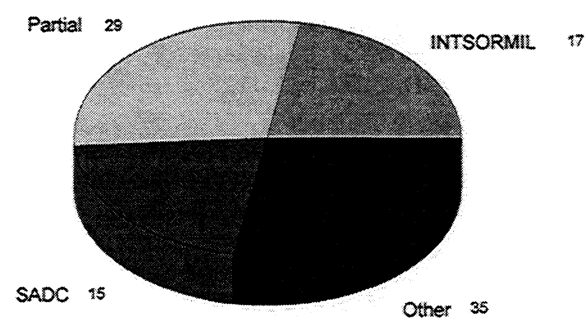


Figure 2. Training analysis - gender breakdown.



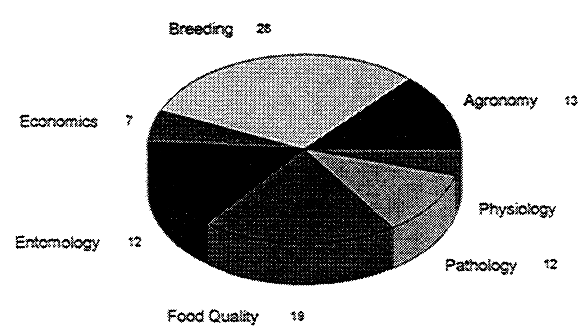
INTSORMIL also places a high priority on training women which is reflected in Figure 2. In 1994, 20% of all INTSORMIL graduate participants were female. Seventeen of the total 96 students received full INTSORMIL scholarships. An additional 29 students received partial INTSORMIL funding and the remaining 50 students were funded from other sources as shown in Figure 3.

Figure 3. Training analysis - source of funding.



All 96 students worked directly with INTSORMIL principal investigators on INTSORMIL projects. These students are enrolled in graduate programs in all seven INTSORMIL disciplines. Figure 4 also shows that there has been a significant increase in the number of students enrolling in food techology, reflecting the importance of product development and food processing.

Figure 4. Training analysis - discipline breakdown.



Total student numbers increased slightly in 1993-94 as compared to 1992 and 1993. However, the number of INTSORMIL funded students has decreased gradually over the years.

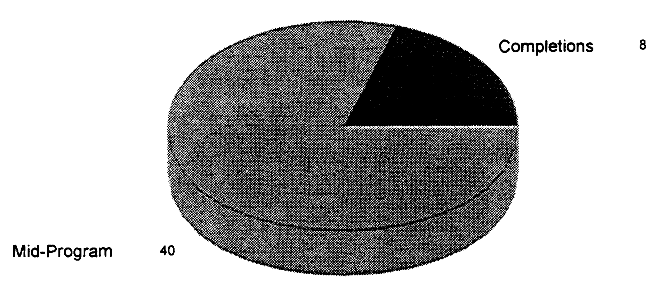
In addition to graduate degree programs, short term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Several Host Country scientists were provided the opportunity to upgrade their skills in this fashion during 1994.

INTSORMIL cooperated with ICRISAT on a ten year special training program for countries of the Southern African Development Community (SADC) which terminated in December, 1993. The SADC/ICRISAT regional Sorghum and Millet Research Program was designed to respond to the need of the 10 member states of SADC, to initiate research on sorghum and millets in the marginal rainfall areas of the region. The program is implemented by ICRISAT and funded by USAID, CIDA and GTZ.

A major component of the program has been Training and Staff Development. The objective of this component has been to strengthen the scientific and technical research capability of National Agricultural Research Programs through advanced degree and technical training. In order to accomplish the objective, ICRISAT has sub-contracted the advanced degree training element to INTSORMIL, the International Sorghum and Millet Collaborative Research Support Program, where the necessary linkages and institutions exist.

The total number of active SADC students is 40 for 1993-94 (Figure 5). SADC funds ended in December of 1993 and most students returned home prior to that date. Students remaining have acquired funding through other sources to complete their degrees.

Figure 5. SADC Training analysis - annual status.



The SADC/ICRISAT Southern African training program held a high profile in INTSORMIL training activities. Of 40 students matriculating in the U.S., Canada and Brazil, 15 are studying under INTSORMIL scientists while the remainder are with subject matter specialists not covered by INTSORMIL scientists. There were 8 degree completions in 1993.

The following tables are a compilation of all INTSORMIL training activities for the period July 1, 1993 through June 30, 1994.

Year 15 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Gono, Lawrence	Zimbabwe	KSU	Agronomy	Vanderlip	PHD	M	S
Lele, Etani	Botswana	KSU	Agronomy	Vanderlip	MSC	M	S
Madulu, Ruth	Tanzania	KSU	Agronomy	Vanderlip	MSC	F	S
Gutierrez, Patricio F.	Ecuador	UNL	Agronomy	Clegg	PHD	M	I
Maliro, Charles	Malawi	UNL	Agronomy	Clegg	PHD	M	S
Ennin, Stella	Ghana	UNL	Agronomy	Clegg	PHD	F	O
Uden, Loren	U.S.	UNL	Agronomy	Clegg	MSC	M	O
Buah, Samuel	Ghana	UNL	Agronomy	Maranville/Andrews	MSC	M	O
Masi, Cassim	Zambia	UNL	Agronomy	Maranville	PHD	M	S
Rivera, Roberto	Honduras	UNL	Agronomy	Maranville	PHD	M	O
Traore, Abdoulaye	Mali	UNL	Agronomy	Maranville	PHD	M	I
Ortega, Augustin Limon	Mexico	UNL	Agronomy	Mason	MSC	M	P
Stockton, Roger	U.S.	UNL	Agronomy	Mason	PHD	M	O
Kamau, Clement K.	Kenya	MSU	Breeding	Gourley	MSC	M	O
Ndulu, Lexingtons	Kenya	MSU	Breeding	Gourley	MSC	M	I
Odouri, Chrispus	Kenya	MSU	Breeding	Gourley	MSC	M	O
Okora, Julius O.	Kenya	MSU	Breeding	Gourley	MSC	M	O
Ouma, Josephine	Kenya	MSU	Breeding	Gourley	PHD	F	O
Kapran, Issoufou	Niger	PRF	Breeding	Axtell	PHD	M	O
Peters, Paul	U.S.	PRF	Breeding	Axtell	PHD	M	P
Cisse, N'Diaga	Senegal	PRF	Breeding	Ejeta	PHD	M	O
Grote, Ed	U.S.	PRF	Breeding	Ejeta	PHD	M	P
Ibrahim, Yahia	Sudan	PRF	Breeding	Ejeta	MSC	M	I
Tuinstra, Mitchell	U.S.	PRF	Breeding	Ejeta	PHD	M	O
Weerasuriya, Yohan	Sri Lanka	PRF	Breeding	Ejeta	PHD	M	P
Gouveia, Sergio Jeremias	Mozambique	TAM	Breeding	Miller	MSC	M	P
Nesbitt, T. Clint	U.S.	TAM	Breeding	Miller	MSC	M	P
Ombakho, George	Kenya	TAM	Breeding	Miller/Rosenow	PHD	M	P
Palma Carias, Alejandro	Honduras	TAM	Breeding	Miller	MSC	M	P
Stewart, Klint G.	U.S.	TAM	Breeding	Miller	MSC	M	P
Tenkouano, Abdou	Burkina Faso	TAM	Breeding	Miller	PHD	M	P
Crasta, Oswald	India	TAM	Breeding	Rosenow	PHD	M	P
Mkhabela, Milton	Swaziland	TTU	Breeding	Rosenow	PHD	M	S
Munera, Alvaro	Colombia	TTU	Breeding	Rosenow	MSC	M	P
Beder, Samy M.	Egypt	TAM	Breeding	Rosenow	VS[1]	M	O
Gebeyehu, Geremew	Ethiopia	TAM	Breeding	Rosenow	VS[1]	M	O
Toure, Aboubacar	Mali	TAM	Breeding	Rosenow	VS[1]	M	I
McCosker, Tony	Australia	TAM	Breeding	Rosenow/Peterson	VS[1]	M	O
Doumbia, Mamadou	Mali	TAM	Breeding	Peterson	PHD	M	O
Katsar, Catherine Susan	U.S.	TAM	Breeding	Peterson/Teetes	PHD	F	O
Jeutong, Fabien	Cameroon	UNL	Breeding	Andrews	PHD	M	O
Abdoulaye, Tahirou	Niger	PRF	Economics	Sanders	MSC	M	I
Ahmed, Mohamed	Sudan	PRF	Economics	Sanders	PHD	M	I
Chiche, Yeshi	Ethiopia	PRF	Economics	Sanders	VS[1]	F	O
Coulibaly, Ousmane	Mali	PRF	Economics	Sanders	PHD	M	O
Garcia, Joao Carlos	Brazil	PRF	Economics	Sanders	VS[1]	M	O
Lawrence, Pareena Gupta	U.S.	PRF	Economics	Sanders	PHD	F	I
Nichola, Tennassie	Ethiopia	PRF	Economics	Sanders	PHD	M	I
Calderon, Pedro	Honduras	MSU	Entomology	Pitre	MSC	M	I
Ching'oma, Godfrey	Malawi	MSU	Entomology	Pitre	MSC	M	S
Portillo, Hector	Honduras	MSU	Entomology	Pitre	PHD	M	I
Bayoum, Imad	Lebanon	TAM	Entomology	Gilstrap	PHD	M	I
Ciomperlik, Matthew	U.S.	TAM	Entomology	Gilstrap	PHD	M	P
Rao, Asha	India	TAM	Entomology	Gilstrap	MSC	F	I
Rojas, E.	Costa Rica	TAM	Entomology	Gilstrap	MSC	M	P
Roque, Javier	Mexico	TAM	Entomology	Gilstrap	PHD	M	P
Diarisso Yaro, Niamoye	Mali	TAM	Entomology	Teetes	PHD	F	O
Magallenes, Ricardo	Mexico	TAM	Entomology	Teetes	PHD	M	P
Mott, Dale Allen	U.S.	TAM	Entomology	Teetes	MSC	M	O
Paliani, Anderson	Malawi	TAM	Entomology	Teetes	MSC	M	S
Alkire, Mark	U.S.	PRF	Food Quality/Util	Butler	MSC	M	P
Lelong, Dolly Bell	Tanzania	PRF	Food Quality/Util	Butler	PHD	F	O
Siame, Anthony Bupe	Zambia	PRF	Food Quality/Util	Butler	PHD	M	S
Tarimo, Thadeo	Tanzania	PRF	Food Quality/Util	Butler	PHD	M	S

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Aboubacar, Adam	Niger	PRF	Food Quality/Util	Hamaker	MSC	M	I
Buckner, Becky	U.S.	PRF	Food Quality/Util	Hamaker	PHD	F	O
Oria, Maria P.	Spain	PRF	Food Quality/Util	Hamaker	PHD	F	I
Weaver, Charlotte	U.S.	PRF	Food Quality/Util	Hamaker	MSC	F	O
Acosta, Harold	Colombia	TAM	Food Quality/Util	Rooney	PHD	M	P
Anderson, Brian	U.S.	TAM	Food Quality/Util	Rooney	MSC	M	P
Asante, Sam	Ghana	TAM	Food Quality/Util	Rooney	PHD	M	P
Beta, Trust	Zimbabwe	TAM	Food Quality/Util	Rooney	MSC	F	S
Cruz y Celis, Laura	Mexico	TAM	Food Quality/Util	Rooney	MSC	F	P
Floyd, Cherie	U.S.	TAM	Food Quality/Util	Rooney	MSC	M	P
Hugo, Leda	Mozambique	TAM	Food Quality/Util	Rooney	MSC	F	S
Lekalake, Rosemary	Botswana	TAM	Food Quality/Util	Rooney	MSC	F	S
Seetharaman, Koushik	India	TAM	Food Quality/Util	Rooney	PHD	M	P
Suhendro, Elly	Indonesia	TAM	Food Quality/Util	Rooney	MSC	F	P
Wright, Lee	U.S.	TAM	Food Quality/Util	Rooney	MSC	M	P
Diourte, Mamourou	Mali	KSU	Pathology	Claflin	PHD	M	O
Lu, Ming	China	KSU	Pathology	Claflin		M	O
Muriithi, Linus M.	Kenya	KSU	Pathology	Claflin	PHD	M	O
Narvaez, Dario	Colombia	KSU	Pathology	Claflin	MSC	M	O
Nzioki, Henry S.	Kenya	KSU	Pathology	Claflin	MSC	M	O
Anderson, Cindy	U.S.	KSU	Pathology	Leslie	M.S.	F	P
Huss, Martin	U.S.	KSU	Pathology	Leslie	PD[2]	M	P
Xu, Jin-Rong	China	KSU	Pathology	Leslie	PHD	M	O
Oh, Boung-.Jun	Korea	TAM	Pathology	Frederiksen	PHD	M	O
Osorio, Jairo	Colombia	TAM	Pathology	Frederiksen	PHD	M	O
Mansuetus, Anaclet	Tanzania	TAM	Pathology	Frederiksen/Odvody	PHD	M	S
Rosewich, Ute L.	Germany	TAM	Pathology	Frederiksen	PHD	F	I
Gandoul, Gandoul I.	Sudan	UNL	Physiology	Eastin	PHD	M	I
Kubic, Keith	U.S.	UNL	Physiology	Eastin	PHD	M	P
Ngulube-Msikita, Rachel	Zambia	UNL	Physiology	Eastin	MSC	F	P
Nyakatawa, Ermson	Zimbabwe	UNL	Physiology	Eastin	MSC	M	S
Petersen, Chris	U.S.	UNL	Physiology	Eastin	MSC	M	O

* I = Completely funded by INTSORMIL
P = Partially funded by INTSORMIL
S = SADC/ICRISAT funded
O = Other source

[1]VS = Visiting Scientist
[2]PD = Post Doctoral

KSU = Kansas State University
MSU= Mississippi State University
PRF = Purdue University
TAM= Texas A&M University
TTU = Texas Tech University
UNL = University of Nebraska - Lincoln

Year 15 SADC/ICRISAT Training Participants

Name	Country	University	Discipline	Advisor	Degree	Gender
Alfredo, Manuel	Angola	Vicosa	Pathology	Ferreira da Silva	MSC	M
Domingos, M'panzo	Angola	Vicosa	Agronomy	Nogueira Fontes	MSC	M
Lele, Etani	Botswana	KSU	Agronomy	Vanderlip	MSC	M
Molapong, Keoagile	Botswana	N. Carolina St.	Plant/Soil	Cox	PHD	M
Khalema, Tieiso	Lesotho	Texas Tech	FSR/Econ	Ervin	MSC	M
Mokhoro, Cyprian	Lesotho	UNL	Food Science	Jackson	MSC	M
Ranthamane, Matla	Lesotho	KSU	Breeding	Bramel-Cox	MSC	M
Sefika, Phakiso	Lesotho	UNL	Forages	Anderson, B.	MSC	M
Ching'oma, Godfrey	Malawi	MSU	Entomology	Pitre	MSC	M
Maliro, Charles	Malawi	UNL	Agronomy	Clegg	PHD	M
Paliani, Anderson	Malawi	TAM	Entomology	Teetes	MSC	M
Brito, Rui	Mozambique	CSU	Agronomy	Durnford	PHD	M
Gouveia, Sergio	Mozambique	TAM	Breeding	Miller	MSC	M
Hugo, Leda	Mozambique	TAM	Food Science	Rooney	MSC	F
Maposse, Inacio	Mozambique	UNL	Forages	Anderson, B.	MSC	M
Mucavele, Firmino	Mozambique	Florida	FSR/Econ	Spreen	PHD	M
Mabuza, Khanyisile	Swaziland	Guelph	Food Science	Gullet	MSC	F
Malaza, Millicent	Swaziland	Penn St.	FSR/Econ	Warland	PHD	F
Matsebula, Sebenzile	Swaziland	Saskatchewan	Biometrics	Baker	PHD	F
Mkhabela, Milton	Swaziland	Texas Tech	Breeding	Rosenow/Nguyen	PHD	M
Kaganda, Suleiman	Tanzania	UNL	Forages	Anderson/Moser	MSC	M
Madulu, Ruth	Tanzania	KSU	Agronomy	Vanderlip	MSC	F
Mansuetus, Anaclet	Tanzanaia	TAM	Pathology	Fredriksen	PHD	M
Matowo, Peter	Tanzania	KSU	Agronomy	Pierzwnski	PHD	M
Mbuya, Odemari	Tanzania	Florida	Agronomy	Boote	PHD	M
Mtwaenzi, Hamis	Tanzania	MSU	Weed Science	Coats	MSC	M
Tarimo, Thadeo	Tanzania	PRF	Bird Control	Butler/Weeks	PHD	M
Chisi, Medson	Zambia	KSU	Breeding	Bramel-Cox	PHD	M
Hikeezi, Doreen	Zambia	KSU	Food Science	Walker	MSC	F
Masi, Cassim	Zambia	UNL	Agronomy	Maranville	PHD	M
Mwale, Moses	Zambia	UNL	Plant/Soil	Walters	MSC	M
Ngulube-Msikita, Rachel	Zambia	UNL	Breeding	Moser	BSC	F
Siame, Anthony	Zambia	PRF	Food Science	Butler	PHD	M
Beta, Trust	Zimbabwe	TAM	Food Science	Rooney	MSC	F
Gono, Tigere Lawrence	Zimbabwe	KSU	Agronomy	Vanderlip	PHD	M
Mahuku, George	Zimbabwe	Guelph	Pathology	Hall	PHD	M
Makaudze, Ephias	Zimbabwe	TAM	FSR/Econ	Fuller	MSC	M
Mazhangara, Edward	Zimbabwe	PRF	FSR/Econ	Masters	MSC	M
Muza, Figuhr	Zimbabwe	UNL	Breeding	Lee	PHD	M
Nyakatawa, Ermson	Zimbabwe	UNL	Agronomy	Eastin/Schilling	MSC	M

CSU = Colorado State University, Fort Collins, Colorado
KSU = Kansas State University, Manhattan, Kansas
MSU= Mississippi State University, Missississippi State, Mississippi
PRF = Purdue University, West Lafayette, Indiana
TAM= Texas A&M University, College Station, Texas
UNL = University of Nebraska, Lincoln, Nebraska

Florida = University of Florida, Gainesville, Florida
Guelph = University of Guelph, Ontario, Canada
N. Carolina St. = North Carolina State University, Raleigh, North Carolina
Penn St. = Penn State University, University Park, Pennsylvania
Saskatchewan = University of Saskatchewan, Saskatoon, Canada
So. Illinois = Southern Illinois University, Carbondale, Illinois
Texas Tech = Texas Tech University, Lubbock, Texas
Vicosa = Universidad Federal de Vicosa, Brazil

INTSORMIL Buy-Ins through FY 94

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
KSU-106	Kansas Sorghum Board	1985	6 years	17,500	105,000
	Kansas Agric. Exp. Station	1989	3 years	19,000	57,000
	Kansas Agric. Exp. Station	1989	3 years	13,333	40,000
	Kansas Sorghum Board	1991	4 years	15,334	61,338
	Kansas Agric. Exp. Station	1990	3 years	19,000	57,000
	EPA/Univ. of Nebraska	1990	2 years	32,518	65,036
					$ 385,374
KSU-108	Kansas Sorghum Board	1985	9 years	18,482	166,338
	Kansas Corn Commission	1988	3 years	16,845	50,535
	Kansas Sorghum Commission	1989	1 year	7,166	7,166
	Kansas Sorghum Commission	1989	1 year	6,500	6,500
	EPA	1990	3 years	39,523	118,569
	Kansas Agric. Exp. Station	1991	3 years	19,000	57,000
	USDA/ARS	1992	1 year	14,400	14,400
					$ 420,508
MSU-104	MIAC/Kenya	1990	2 years	115,725	231,450
	MIAC/Kenya	1992	3.5 years	142,000	497,000
					$ 728,450
MSU-105	FAO	1992	3 years	2,245	**$ 6,735**
MSU-111	Fedearroz	1990	5 years	10,000	50,000
	El Alcaravan Foundation	1990	2 years	200,000	400,000
	Fenalce	1991	1 year	5,000	5,000
					$ 455,000
PRF-103A	AID/Program Support Grant	1988	2 years	7,500	15,000
	Agric. Exp. Station	1988	2 years	6,000	12,000
	Purdue Agronomy Dept.	1989	2 years	1,000	2,000
	McKnight Foundation	1989	3 years	250,000	750,000
	Corporation for Science & Tech.	1991	1 year	10,000	10,000
	Pioneer Hi-Bred Intern.	1992	3 years	33,900	101,693
	Purdue Agronomy Dept.	1992	1 year	1,000	1,000
	McKnight Foundation	1992	3 years	250,000	750,000
					$ 1,641,693
PRF-103B	USDA Training	1989	3 years	15,000	45,000
	AFGRAD Training	1989	4 years	9,000	36,000
	NAAR Project	1991	1 year	3,000	3,000
					$ 84,000
PRF-104B & 104C	USAID PSG	1989	2 years	7,500	15,000
	Rockefeller Foundation	1989	3 years	23,067	69,200
	USAID/PSTC	1990	4 years	37,450	150,000
	USAID PSG	1991	2 years	10,000	20,000
	Purdue Research Foundation	1991	1 year	2,800	2,800
	Pioneer Seed Co.	1991	3 years	40,000	120,000
	PSTC/USAID	1991	3 years	50,000	150,000
	Pioneer Seed Co.	1991	2 years	30,000	60,000
	NSF	1992	1.5 years	173,333	260,000
	Pioneer Seed Co.	1993	2 years	13,600	27,192
					$ 874,192
PRF-105	USAID PSG	1989	4 years	5,000	20,000
	USAID PSG	1989	3 years	5,000	15,000
	World Bank	1989	2.5 years	10,000	25,000
	World Bank/IDA	1989	1 year	4,500	4,500
	USAID/Bean-Cowpea CRSP	1990	1 year	27,000	27,000
	EMBRAPA	1992	1 year	10,000	10,000
	USAID/AFT/ARTS	1992	1 year	20,000	20,000
					$ 121,500
PRF-107	Purdue Agronomy Dept.	1988	1 year	1,500	1,500
	State of Indiana	1990	1 year	7,000	7,000
	McKnight Foundation	1990	3 years	20,632	61,896
	USAID PSG	1990	2 years	14,000	28,000
	McKnight Foundation	1990	3 years	22,000	66,000
	Pioneer Seed Co.	1991	2 years	30,000	60,000
	State of Indiana	1991	1 year	1,200	1,200
					$ 225,596
PRF-109	USDA Grant	1990	2 years	60,000	**$ 120,000**

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
TAM Joint	USAID/TAMU	1989	3 years	15,000	45,000
	USAID/TAMU	1991	3 years	15,000	45,000
					$ 90,000
TAM-122	State of Texas Grant	1989	2 years	20,000	40,000
	USAID/TAMU	1990	2 years	10,000	20,000
	USAID/TAMU	1990	3 years	13,000	39,000
	Texas Higher Coordinating Board	1991	2 years	27,000	54,000
	USDA	1991	2 years	7,500	15,000
	USAID/TAMU	1992	2 years	28,000	56,000
					$ 224,000
TAM-123	Texas Grain Sorghum Producers	1990	5 years	50,000	250,000
	USAID/TAMU	1990	1 year	17,000	17,000
	USAID/TAMU	1991	1 year	28,000	28,000
					$ 295,000
TAM-124	USDA	1989	3 years	10,000	30,000
	Texas Advanced Research	1989	1 year	75,000	75,000
	TAES/ERA	1989	2 years	32,000	64,000
	Texas Advanced Research	1990	3 years	15,000	45,000
	Rockefeller Foundation	1990	2 years	30,000	60,000
	Texas Advanced Research	1992	2 years	10,000	20,000
	Rockefeller Foundation	1992	2 years	7,000	14,000
					$ 308,000
TAM-125	TAMU/PSG	1989	2 years	45,000	90,000
	Industry Grant	1989	2 years	10,000	20,000
	USDA/CRSP	1989	1 year	15,000	15,000
	USDA/APHIS	1989	2 years	15,000	30,000
	USDA/APHIS	1989	1 year	14,000	14,000
	Texas Agric. Exp. Station	1990	2 years	7,000	14,000
	USDA/APHIS	1990	3 years	23,734	71,202
	USDA/CSRS	1990	2 years	59,819	119,638
	TAMU/Program Support Grant	1990	2 years	18,638	37,276
	TAMU/Program Support Grant	1990	2 years	30,000	60,000
	Texas Grain Sorghum Producers	1990	2 years	50,000	100,000
	USDA/APHIS	1991	1 year	13,200	13,200
	TAMU/Program Support Grant	1990	3 years	27,000	81,000
	Texas Grain Sorghum Producers	1993	5 years	25,000	125,000
					$ 790,316
TAM125-B	TAES	1993	2 years	29,000	58,000
	USDA/APHIS	1993	4 years	32,500	130,000
	USDA/CSRS-SR	1993	2 years	45,000	90,000
	USDA/APHIS	1993	4 years	15,000	60,000
					$ 338,000
TAM-126	Texas Center for Energy	1989	1 year	14,500	14,500
	TAMU/Program Support Grant	1989	3 years	10,000	30,000
	Texas Agr. Exp. Station	1989	5 years	50,000	250,000
	TAES/ERA	1990	2 years	25,000	50,000
	HATCH	1990	4 years	35,000	140,000
	Texas Sorghum Producers	1990	1 year	15,000	15,000
TAM-126	Grain Sorghum Producers	1991	3 years	10,300	30,900
(Cont.)	TAMU/Hatch	1992	5 years	31,184	155,920
	TAES/ERA	1990	2 years	19,000	38,000
	Grain Sorghum Producers	1992	2 years	20,000	40,000
					$ 764,320
TAM-131	USAID/Honduras PL480	1990	1 year	111,395	111,395
	USAID/Honduras PL480	1991	1 year	120,000	120,000
	USAID/Honduras PL480	1992	1 year	88,704	88,704
	USAID/Honduras PL480	1993	1 year	88,704	88,704
	Commercial Seed Co.	1992	1 year	7,000	7,000
	EEC/IICA/PRAIG	1992	3 years	9,260	27,780
	EEC/IICA/PRAIG	1993	3 years	10,975	32,920
					$ 476,503
UNL-113	Rockefeller Foundation	1988	3 years	8,333	25,000
	Ministry of Science (Leave)	1991	1 year	25,000	25,000
					$ 50,000
UNL-114	German Acad.Exchange Serv.	1993	2.5 years	11,000	**$ 27,500**
UNL-115	Michigan State/Senegal Agric.	1989	3 years	46,700	140,000
& 118	USAID/Dakar	1992	5 years	70,000	350,000
					$ 490,000

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
UNL-116	Elliott Grant	1986	4 years	17,250	69,000
	USDA/OICD	1989	3 years	14,667	44,000
	Nebraska Sorghum Board	1990	3 years	24,00	72,000
	USAID/OICD	1990	3 years	43,000	129,000
	USAID/OICD	1990	1 year	4,000	4,000
					$ 318,000
UNL-123	USAID/PSTC Grant	1989	3 years	50,000	150,000
	USDA/ARS	1986	5 years	22,669	113,345
	USDA/ARS	1991	5 years	24,356	121,780
					$ 385,125
M.E.	INTSORMIL/Egypt/NARP Nebraska/Kansas St.	1991	3 years	156,727	$ 470,183
	SADC/ICRISAT/INTSORMIL Training	1990	5 years	1,280,400	6,402,039
	AID/CROSS CRSP Activities	1990	1 year	100,000	100,000
	USAID/Botswana/DAR	1990	1 year	35,860	35,860
	USAID/Khartoum/ARC	1990	1 year	80,000	80,000
	Social Science Research Workshop	1991	1 year	31,600	31,600
	Adaptation of Plants to Soil Stress Workshop	1992	1 year	25,000	25,000
	Rockefeller Foundation-Conference	1993	1 year	6,500	6,500
	FAO/IAR Ethiopia Training	1994	1 year	20,000	20,000
					$ 7,171,182
Total Buy-Ins					**$ 16,790,994**

INTSORMIL
Sponsored and Co-Sponsored Workshops
1979 - 1994

	Name	Where	When
1.	International Short Course in Host Plant Resistance	College Station, Texas	1979
2.	INTSORMIL PI Conference	Lincoln, Nebraska	1/80
3.	West Africa Farming Systems	West Lafayette, Indiana	5/80
4.	Sorghum Disease Short Course for Latin America	Mexico	3/81
5.	International Symposium on Sorghum Grain Quality	ICRISAT	10/81
6.	International Symposium on Food Quality	Hyderabad, India	10/81
7.	Agrimeteorology of Sorghum and Millet in the Semi-Arid Tropics	ICRISAT	1982
8.	Latin America Sorghum Quality Short Course	El Batan, Mexico	4/82
9.	Sorghum Food Quality Workshop	El Batan, Mexico	4/82
10.	Sorghum Downy Mildew Workshop	Corpus Christi, Texas	6/82
11.	Plant Pathology	CIMMYT	6/82
12.	Striga Workshop	Raleigh, North Carolina	8/82
13.	INTSORMIL PI Conference	Scottsdale, Arizona	1/83
14.	INTSORMIL-ICRISAT Plant Breeding Workshop	CIMMYT	4/83
15.	Hybrid Sorghum Seed Workshop	Wad Medani, Sudan	11/83
16.	Stalk and Root Rots	Bellagio, Italy	11/83
17.	Sorghum in the '80s	ICRISAT	1984
18.	Dominican Republic/Sorghum	Santo Domingo	1984
19.	Sorghum Production Systems in Latin America	CIMMYT	1984
20.	INTSORMIL PI Conference	Scottsdale, Arizona	1/84
21.	Primer Seminario National Sobre Produccion y Utilizacion del Sorgo	Santo Domingo, Dominican Republic	2/84
22.	Evaluating Sorghum for Al Toxicity in Tropical Soils of Latin America	Cali, Colombia	4/84
23.	First Consultative and Review on Sorghum Research in the Philippines	Los Banos, Philippines	6/84
24.	INTSORMIL Graduate Student Workshop and Tour	College Station, Texas	6/84
25.	International Sorghum Entomology Workshop	College Station, Texas	7/84
26.	INTSORMIL PI Conference	Lubbock, Texas	2/85
27.	Niger Prime Site Workshop	Niamey, Niger	10/85
28.	Sorghum Seed Production Workshop	CIMMYT	10/85
29.	International Millet Conference	ICRISAT	4/86
30.	Maicillos Criollos and Other Sorghum in Middle America Workshop	Tegucigalpa, Honduras	12/87
31.	INTSORMIL PI Conference	Kansas City, Missouri	1/87
32.	2nd Global Conference on Sorghum/Millet Diseases	Harare, Zimbabwe	3/88
33.	6th Annual CLAIS Meeting	San Salvador, El Salvador	12/88
34.	International INTSORMIL Research Conference	Scottsdale, Arizona	1/89
35.	INTSORMIL Graduate Student Workshop and Tour	College Station, Texas	7/89
36.	ARC/INTSORMIL Sorghum/Millet Workshop	Wad Medani, Sudan	11/89
37.	Workshop on Sorghum Nutritional Grain Quality	West Lafayette, Indiana	2/90
38.	Sorghum for the Future Workshop	Cali, Colombia	1/91
39.	INTSORMIL PI Conference	Corpus Christi, Texas	7/91
40.	Social Science Research and the CRSPs	Lexington, KY	6/92
41.	Workshop on Adaptation of Plants to Soil Stresses	Lincoln, NE	8/93
42.	Application of Genetics and Biotechnology to the Characterization of Fungal Pathogens of Sorghum and Millet	Bellagio, Italy	11/93

INTSORMIL
1993-1994 Publications

Almeida Dominguez, H.D. and L.W. Rooney. 1994. Propiedades de malta diastasica de sorgo blanco. Archivos Latino Americanos de Nutricion, Vol 44(1)23-28.

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