Improvement of Pigeonpea in Eastern and Southern Africa

Annual Research Planning Meeting 1994

International Crops Research Institute for the Semi-Arid Tropics

Abstract

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This publication is a report of the second Annual Research Planning Meeting of the ICRISAT/African Development Bank Pigeonpea Improvement Project. The 35 delegates included scientists and senior research administrators from nine countries in the southern and eastern Africa region (Kenya, Lesotho, Malawi, Namibia, Sudan, Swaziland, Tanzania, Uganda, and Zambia), and from ICRISAT. Progress made in collaborative pigeonpea research was reviewed at the Meeting, and detailed workplans and budgets formulated for research and extension work in each country for the 1994/95 crop season. The recommendations made at the Meeting stress several aspects, including the need for more rapid technology transfer, better availability of seed, regional nurseries for drought and wilt resistance screening, and more training programs, especially on pigeonpea utilization, in order to increase both local consumption and export.

Résumé

Amélioration du pois d'Angole en Afrique orientale et australe—Réunion annuelle 1994 sur la planification de la recherche, 21–23 septembre 1994, Nairobi, Kenya. Cette publication est un compte rendu de la deuxième Réunion annuelle sur la planification de la recherche du Projet ICRISAT/Banque africaine de développement d'amélioration du pois d'Angole. La réunion a été assistée par 35 chercheurs et administrateurs seniors provenant de neuf pays de l'Afrique orientale et australe (Kenya, Lesotho, Malawi, Namibie, Soudan, Swazilande, Tanzanie, Ouganda et Zambie) et de l'ICRISAT. Les progrès enregistrés dans les efforts concertés sur le pois d'Angole ont été passés en revue. Des plans de travail et de budget ont été précisés pour des travaux de recherche et de vulgarisation dans chaque pays de la région pour la campagne 1994/95. Les recommandations ont souligné plusieurs aspects, dont le besoin de transfert rapide de technologie, une meilleure disponibilité de semences, des pépinières régionales de criblage pour la résistance à la sécheresse et au flétrissement, davantage de programmes de formation surtout sur l'utilisation du pois d'Angole afin d'accroître la consommation locale et d'exportation.

Sumario

Melhoramento de grao en Africa Oriental e Africa do Sul. Reunido do planejamento investigatorio 1994, 21-23 Sep 1994, Nairobi, Kenya. Essa publicao e uma reportagem da Segunda Reuniao do Planejamento Investigatorio do ICRISAT/Banco do desenvolvimento Africano para o projeto do melhoramento do gr§o. Os 35 participantes, incluiram cientistas, investigadores de nove pafses em Africa do Sul e Africa Oriental, esses s§o (Kenya, Lesotho, Malawi, Namibia, Sudan, Swazilandia, Tanzania, Uganda, e Zambia) e de ICRISAT. Progreso feito nas investigacoes sobre o grao foi revisto nessa reuniao. Detalhados pianos e orcamentos foram tambem formulados para as investigacoes e trabalho da extencao em cada pafs para estacao do cultivo 1994/95. Nas recomendacoes feitas nessa reuniao a emfase foi posta nos varios aspetos, esse incluem, a necessidade para uma mais rapida transferencia da tecnologia, melhor disponibilidade da sememente, sementeiras para as secas, selecao para resistencia a murcho e mais programas do treino especialmente no uso do grao, em vista de aumentar o consumo local e tambem para a exportacao.

Improvement of Pigeonpea in Eastern and Southern Africa

Annual Research Planning Meeting 1994

Nairobi, Kenya, 21-23 Sep 1994

Edited by

S N Silim, S B King, and S Tuwafe

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
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1995

Contents

Introductory Session

Welcome Address

C G Ndiritu[1]

Let me at the onset welcome you, on behalf of the Government of Kenya, the Kenya Agricultural Research Institute (KARI), and on my own behalf, to this Review and Planning Meeting on pigeonpea research and improvement in southern and eastern Africa. The meeting has been organized by ICRISAT and KARI, while the project of which it is a part is funded by the African Development Bank. I hope you have had enough time to rest, and are ready for the task ahead of you for the next 3 days.

As you are aware, pigeonpea has been grown in Africa for more than 4000 years; eastern Africa is considered a secondary center of diversity. In Kenya alone, pigeonpea is grown on over 200 000 ha annually, and ranks first amongst the grain legumes in the major production areas. These are semi-arid areas characterized by high temperatures, low and erratic rainfall, and poor soils. The importance of pigeonpea in the dryland areas of Kenya and in the region at large needs no emphasis. The crop is drought-tolerant, producing yields in seasons when other crops fail. The protein-rich grain is an important component in the diet of subsistence farmers, who eat mainly low-protein cereals and root crops. The crop is an important component in the sustainability of dryland farming systems because of its ability to incorporate nitrogen into the soil through atmospheric nitrogen fixation, leaf fall, and nutrient cycling. Pigeonpea stems supplement an often deficient fuelwood situation. The crop provides an assured source of income for farm families and foreign exchange for Kenya.

In Kenya, pigeonpea is grown for grain and green peas. Grain is for home consumption and sale to traders, while most of the green pods are consumed on-farm (a small quantity is exported). About 7000 t of *dhal* (dehulled pigeonpea) and 15 000 t of whole grain are exported annually to Europe, North America, the Middle East, and India, but this figure represents just 30% of Kenya's export potential.

Despite the importance of pigeonpea in Kenya and elsewhere in the region, little concerted research effort has been directed at either crop improvement or technology transfer. Yields on farmers' fields are low, averaging 300-500 kg ha^{*1}. A number of factors are responsible—drought, lack of improved cultivars, poor crop husbandry, pests, and diseases. KARI recognizes the importance of the crop. That is why in the first instance we allowed the placement of ICRISAT scientists in Kenya to conduct collaborative research with scientists from Kenya and other countries in the region. The results of such collaborative work will help lead us towards self sufficiency and food security. To emphasize our commitment to this crop, in our 5-year development plan, we have committed substantial resources to pigeonpea (and to all the grain legumes).

Over the next 3 days, you will have the opportunity to share experiences, identify the constraints limiting production, consumption, and marketing, and develop a re-

1. Director, Kenya Agricultural Research Institute, P O Box 57811, Nairobi, Kenya.

search agenda to alleviate them. The heads of states in the region have emphasized the need for integration. In meetings like this we should identify areas where collaboration is needed in order to avoid duplication and wastage of our meager resources.

Research work in the region (especially in Kenya) and at ICRISAT Asia Center in India has resulted in the development of extra short and short-duration cultivars that mature in 100-150 days. Some of these cultivars have been widely tested in the region and their potential determined for specific locations. They must now be transferred to farmers. And it is your responsibility—the responsibility of the national scientists assembled here—to ensure that this transfer takes place quickly and effectively. In much of the region, long-duration pigeonpea is intercropped with cereals and other annuals. We need to develop stable, high-yielding, long-duration varieties and improved production packages that will not only improve yield, but also lead to sustainability and an improved life for the rural community.

In conclusion, I wish you success in your deliberations, and hope that not only you, but also pigeonpea farmers throughout southern and eastern Africa, will benefit from this Meeting.

About the Meeting

S N Silim[1]

Let me add my welcome to that of the KARI Director.

Since the Pigeonpea Improvement Project was launched in Mar 1992 with funding from the African Development Bank, we have come a long way.

- We have implemented parts of our research agenda, and initiated work on several other aspects.
- We have met each year to review workplans for further research.
- Higher-degree training is progressing well.
- It has been emphasized that we need to widen the production base by commercializing the crop and developing different processing and utilization methods. We now have a consultant (who is attending this Meeting) who will meet representatives of the various national programs to chalk out detailed workplans on processing and utilization.
- A consultant in pest management—another important constraint—is also here. She will discuss with you workplans on entomology and integrated pest management.

We realize that pigeonpea is an important crop in the region, for many reasons:

- It supplements the largely cereal/starch-based diet of the local population.
- It contributes to the sustainability of farming systems because of its ability to fix nitrogen and solubilize phosphorus (which is otherwise unavailable), thus making it available to itself and to the succeeding crop.
- It is tolerant of low-moisture conditions, and can therefore produce yields in drought-prone areas where other crops fail.

From the very beginning, this project has been NARS-driven, based on the perception that the crop is important in your respective countries. There is therefore a need for commitment—from each country—to provide inputs, both human and financial, to conduct research leading to the improvement of pigeonpea production. Our aim should be to:

- Develop technologies with farmer involvement to improve pigeonpea production and pigeonpea-based cropping systems.
- Broaden the base of utilization.

To this end, I urge you that technologies developed must be tested and transferred to the farmer—we should aim at impact on farmers' fields. I believe a number of countries have identified short-duration varieties that in some instances have been tested on-farm. When we develop workplans, let us emphasize the transfer of technology to farmers. In the process we should address the issues of on-farm trials, demonstration, seed multiplication, and production-related constraints that a smallholder farmer may face.

1. ICRISAT Pigeonpea Project, P O Box 39063, Nairobi, Kenya.

We should not, however, forget that the major cropping systems in the region are based on long- and medium-duration pigeonpea. Research that leads to the improvement of these varieties and cropping systems is required. Other issues, such as biotic and abiotic constraints and how to alleviate them, also need to be addressed.

During the course of the Meeting, scientists from the national programs in our region will present their results. Some of their work may have application across countries. I therefore urge you, during this Meeting, to develop plans for collaborative research with such countries.

As you are aware, pigeonpea research has not received much attention; there are only a few scientists working on the crop. Training is a fundamental objective of the Project, and we have circulated forms on which you can indicate specific training needs for your country. Please complete these forms and return them to the organizing committee.

Pigeonpea Improvement in Kenya

D K Muthoka[1]

Introduction

Kenya is the world's second largest producer of pigeonpea *(Cajanus cajan),* which is the second most important pulse crop in the country (after field beans, *Phaseolus vulgaris).* Production is concentrated in Machakos, Makueni, Kitui, Mwingi, Meru, Lower Embu, Nyambene, and Tharaka-Nithi districts in Eastern Province; the drier parts of Kirinyaga, Murang'a, and Kiambu districts in Central Province; and some parts of Lamu, Kilifi, Kwale, Tana River, and Taita-Taveta districts in Coast Province. The crop is rainfed and normally intercropped with cereals (maize, sorghum) and short-duration legumes (beans, cowpea). Farmers grow long-duration pigeonpea varieties with minimal inputs, and usually obtain low yields (0.4-0.6 t ha^{-1}). The low productivity is due to several factors: low-yielding cultivars, lack of quality seeds, diseases and insect pests, poor production practices, and environmental and socio-economic factors (Kimani et al. 1994).

The central objective of the national food security policy is to ensure adequate nutrition throughout the country. Drought-tolerant crops must therefore play a major role, especially in the ASAL (arid and semi-arid land) areas. Pigeonpea provides several important benefits. It is a source of cheap protein and firewood, and can improve soil fertility and help prevent soil erosion.

Pigeonpea research in Kenya

Pigeonpea research work in Kenya started in 1977 at the University of Nairobi and in 1980 at the National Dryland Farming Research Centre (NDFRC) at Katumani. Considerable progress has been made since then on developing improved varieties and production practices. Scientists at NDFRC-Katumani have developed various varieties for three maturity groups, for different agroecological zones.

- Short-duration (agroecological zones 4 and 5) - four genotypes are recommended, Kat 60/8, 50/3, IIRA, and 109, which flower in 80 days and mature in 150 days.
- Medium-duration (agroecological zone 4) - three genotypes are recommended, Kat 777, 81/3/3, and 657/1, which flower within 100 days and mature in 180 days.
- Long-duration - improved landraces that flower within 130 days and mature in 210 days. These varieties complete their vegetative growth during the hot period (Oct-Mar) and their reproductive period during the cool months (Mar-Jul).

1. National Dryland Farming Research Centre-Katumani, P O Box 340, Machakos, Kenya.

To ameliorate the various constraints to pigeonpea production in the country, NDFRC is collaborating with ICRISAT in germplasm exchange, multilocational trials, on-farm research, and seed production.

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Kimani, P.M., Omanga, P.A., and Silim, S.N. 1994. Status of pigeonpea research in Kenya, and future prospects. Pages 37-44 *in* Improvement of pigeonpea in eastern and southern Africa: Annual Research Planning Meeting 1993, 25-27 Oct 1993, Bulawayo, Zimbabwe (Silim, S.N., Tuwafe, S., and Laxman Singh, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Pigeonpea Improvement in Malawi

J T Munthali[1] (Read by H N Soko[2])

Pigeonpea is a very important crop in Malawi; for both human consumption and for livestock feed. The Malawi government policy on pigeonpea research and development addresses the following issues:

Food security. Pigeonpea is grown mostly in the southern and central regions of the country. These traditional pigeonpea-growing areas are characterized by short rainfall duration (550-750 mm, Nov-Mar) and terminal drought with intermediate to high temperatures. Crop failures of the staple food crops (maize and sorghum) are common, and cause severe food shortages in these areas. Because pigeonpea is relatively drought-tolerant and a valuable protein-rich diet supplement, the government places considerable emphasis on increasing production.

Sustainable production. Pigeonpea, being a legume, fixes nitrogen in the soil and thus improves soil fertility wherever it is grown. As an intercrop in various farming systems it also contributes to soil and water conservation.

Potential production areas. The crop in Malawi is largely produced by smallholder farmers, who may be unable to significantly increase the area of sole-cropped pigeonpea because their landholdings are limited. However, pigeonpea area can be increased by encouraging its use as an intercrop, and by extending its cultivation to non-traditional areas (usually characterized by cool weather during the growing season). The government recognizes the need for new ideotypes if cultivation is to be expanded to new areas.

Utilization, processing, and agro-industry. Increased pigeonpea production would lead to increased utilization, processing, and marketing, both locally and for export. The development of agroprocessing channels would increase farmers' incomes, and eventually generate foreign exchange for the country.

Research activities. The government recognizes that in order to increase pigeonpea production, research should be strengthened. Research activities should focus on solving the major production constraints:

- Lack of improved varieties—both on-station and on-farm research should be intensified to develop high-yielding, adaptable genotypes in each maturity group, for cultivation in the various agroecosystems in Malawi.

1. Chief Agricultural Research Officer, Ministry of Agriculture, Department of Agricultural Resources, P O Box 30134, Lilongwe, Malawi.
2. Chitedze Agricultural Research Station, P O Box 158, Lilongwe, Malawi.

- Nonavailability of seed—the government intends to put into place a system for seed production and distribution, especially for smallholder farmers. However, funding for such activities has always been a limiting factor; financial and logistic assistance from NGOs and international research and donor institutions would be appreciated.

Training. Training of scientists and technical support staff is a prerequisite to efficient and successful research. The government of Malawi greatly appreciates the assistance provided by the ICRISAT Pigeonpea Improvement Project in training government scientists and technical support staff.

Collaboration with other institutions. The government acknowledges with thanks the collaboration that exists between the national program and the ICRISAT Pigeonpea Project (which is based at Chitedze) on improving pigeonpea research, production, processing, and utilization in Malawi. We hope this relationship between ICRISAT and the government of Malawi will be sustained, and even further strengthened.

Government Policy on Pigeonpea Research and Development in Tanzania

G M Mitawa[1]

Introduction

Pigeonpea is an important pulse crop in Tanzania, where it is grown mainly in low-altitude areas, e.g., in the southern parts and the lowland coastal areas. Equally important as production centers are the medium-altitude areas in the northern (Babati district) and western parts (Urambo district in the Tabora region) of the country.

The Tanzanian government is fully aware of the considerable potential for increasing production and export of pulses, including pigeonpea. In spite of this realization, however, area under pulses has remained static at about 550 000 ha between 1984/85 and 1988/89 (MALD 1990), while production has remained between 380 000 and 420 000 t over the same period. However, exports of pulses have steadily increased. The government now places great emphasis on increasing the production of low-volume, low-value crops such as pigeonpea, and developing the non-traditional export sector. For example, pigeonpea being drought-tolerant, its production could be expanded to include the marginal-rainfall areas of the central plateau.

Policy guidelines

The National Agricultural Policy of 1992 (MoA 1992) mentions pulses in general but does not deliberate specifically on pigeonpea. To enhance production and exports, the policy recommends that:

- Research efforts be made to raise productivity of pulses by selection and breeding for better quality, high yield, and insect and disease resistance
- Deliberate efforts should be made to increase output both through area expansion and the use of high-yielding varieties for local and export markets
- Concerted efforts should be made to prevent pre- and postharvest losses
- Whenever possible, industrial processing of pulses (e.g., pigeonpea *dhal)* should be encouraged to improve the quality of export products and increase value addition.

Research on pigeonpea

The main constraints to pigeonpea production in Tanzania are lack of improved cultivars, pest damage on the long-duration landraces, diseases (especially fusarium

1. Department of Research and Training, P O Box 2066, Dar es Salaam, Tanzania.

wilt), and poor management practices (Mligo and Myaka 1994). Progress to date on pigeonpea research in Tanzania is discussed elsewhere in this publication. The Ministry of Agriculture, through its Department of Research and Training, intends to strengthen these efforts by encouraging collaboration with other institutions in the region working on pigeonpea. There are plans to collaborate with ICRISAT and the Natural Resources Institute (NRI), UK, in various studies.

Marketing and seed availability

Pigeonpea production in Tanzania has been hampered by inadequate or delayed supply of inputs (particularly fertilizers and insecticides) and inadequate marketing channels. The road network is poor, and after the collapse of the General Agricultural Produce and Export Organization (GAPEX), the private sector marketing machinery is not sufficiently developed to handle non-traditional export crops (MoA 1994). The government has now liberalized input procurement, supply, and distribution regulations to boost the non-traditional export sector. Furthermore, private sector and smallholder producers will be given increased importance, and direct government involvement in agricultural production will be reduced.

These strategies, it is hoped, will ensure that smallholder farmers get agricultural inputs (e.g., chemicals) as and when required. Private sector participation in marketing is expected to help farmers find a ready market for their produce, and thus gradually increase area and production.

To develop and make available high-yielding varieties, the National Grain Legume Research Program is running a series of trials of short-, medium-, and long-duration varieties. A number of promising lines have been identified and some are already earmarked for on-farm testing (Mligo and Myaka 1994). Furthermore, through our collaboration with ICRISAT, we should be able this season to deploy four new dwarf pigeonpea varieties, ICPLs 86005, 87091, 87109, and 87 W. These will be evaluated in on-farm trials on cassava-pigeonpea intercropping.

Getting improved seed of most of these low-volume, low-value crops is not a simple task. Various strategies need to be tested, including giving smallholder farmers small samples of improved seed free of charge. A proposal is now being developed to facilitate the organization of Farmer Seed Production Groups that will function similarly to the informal (usually barter) system used by farmers in the Lake Victoria basin. When these Groups become operational, improved varieties of pigeonpea (and other crops) will have a well-established mechanism for seed multiplication and distribution at village level.

Pre- and postharvest losses

The use of resistant varieties can help reduce yield and quality losses as a result of pests and diseases, and breeding for resistance to specific pests and diseases is an important objective of our research program.

Rather than emphasize the use of insecticides and fungicides (which are associated with high costs and potential damage to the environment), the current policy thrust is to develop and popularize integrated pest management (IPM) strategies. Several IPM-based projects have been developed, including a collaborative proposal between the Department of Research and Training and NRI, to study smallholder mixed cropping for the control of *Striga* in cereal crops and fusarium wilt in cotton and pigeonpea. Research planning has begun on a cassava-pigeonpea intercropping system to study the effects of pigeonpea on cassava pests (primarily the cassava mealy bug) and diseases (African cassava mosaic virus).

Conclusion

Although the Agricultural Policy of Tanzania does not specifically mention pigeonpea, the strategies developed to implement the general policy guidelines seem to favor the production of pigeonpea. The increased level of collaboration with institutions working on pigeonpea is an indication of this trend. It is hoped that private sector participation will improve marketing, and enhance the production of pigeonpea for local and export markets.

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Pigeonpea in Ugandan Agriculture

J P Esele[1]

Introduction

Uganda's economy is dominated by agriculture, which accounts for 60% of GDP, over 95% of export earnings, 80% of employment, and 40% of government revenue. The government recognizes the need to diversify exports and particularly to place less reliance on increased coffee and cotton production, in view of the world market situation.

Food crops are now increasingly important in cash terms. The main earners for rural families are now food crops or dairy products that are sold in urban areas, rather than the export crops of the 1970s. Today, food crops dominate the contribution of agricultural production to GDP.

The need for research

During the last decade, productivity of all major crops in Uganda has either remained stagnant or declined; whatever production increases have been realized have been due to an expansion in cultivated area, rather than higher yields. Yields of almost all crops in the country are lower than in most developed countries. The main causes of low productivity are:

- Lack of improved cultivars
- Prevalence of pests and diseases
- Lack of improved agronomic and postharvest technologies acceptable to farmers
- Declining soil fertility
- Very low use of inputs (fertilizers and pesticides).

Research results indicate that crop yields can be more than doubled with the use of improved varieties and production technologies. Some of these new technologies are, however, yet to be fully tested at farm level. The national agricultural policy is to raise yields by the development and adoption of appropriate technology, achieved through strengthened agricultural research and extension services. Technology change is envisaged to play an increasingly important role in agricultural growth.

Pigeonpea production, importance, and uses

Pigeonpea is an important food crop of the rural poor in the dry areas of northern and northeastern Uganda. The major production areas are Apac, Lira, Gulu, Kitgum,

1. Serere Agricultural and Animal Production Research Institute, P O Soroti, Uganda.

Arua, Soroti, and Kotido. Production is increasing in Mbale, Masindi, and Hoima districts. In 1992, an estimated 53 000 t were produced from 63 000 ha (Table 1).

Pigeonpea is consumed locally as a sauce and the crushed, dried seed is processed into *dhal.* The stems are used as fuelwood and in the construction of huts and baskets. Traditional varieties in particular have a good potential for use in agroforestry programs. The crop has the potential to generate substantial benefits for the rural poor. Pigeonpea also has other uses:

- As a protein-rich diet supplement (protein deficiencies are common in many areas of the country)
- As a possible non-traditional export crop
- As feed, in the growing livestock industry
- As a rotation crop between cereals, since it is a nitrogen fixer.

Production potential

Pigeonpea is either sole-cropped in rotation with cereals or intercropped, mostly with cereals (sorghum/millet). Yields are presently very low (0.3-0.5 t ha^{-1}). This can be increased to 1.5-2 t ha^{-1} with improved varieties and production packages and proper pest management. Some varieties with even higher yield potentials are available with ICRISAT, and could be introduced and advanced for production in the country.

Table 1. Area and production of pigeonpea in Uganda by district, 1990-92.

	Area (ha)			Production (t)		
	1990	1991	1992	1990	1991	1992
Apac	13 053	12 632	11 410	10 834	10 678	9 663
Arua	941	1 119	1 049	781	946	889
Gulu	8 619	17 379	8 125	7 154	6 238	6 881
Hoima	470	238	214	390	195	172
Iganga	139	134	110	115	113	94
Kitgum	23 328	20 133	25 685	19 362	17 017	21 317
Kotido	515	2 309	2 370	427	1 951	2 007
Lira	13 595	14 669	13 248	11 284	12 397	11 220
Masindi	129	122	121	107	103	102
Mbale	305	296	256	253	521	216
Moroto	16	15	16	13	12	12
Moyo	26	25	29	22	21	25
Mukono	10	7	6	8	6	5
Nebbi	69	67	63	57	57	53
Soroti	456	441	234	378	372	308
Kibaale	0	46	67	0	46	67
Total	61 671	59 631	63 133	51 185	50 403	53 031

Current and future research

Current research efforts in various disciplines are presented elsewhere in this publication. Ugandan farmers currently grow traditional varieties which, in addition to being low yielders, are also of long duration, taking 6-9 months to mature. New varieties yield 200% more and mature in about half that time. It is therefore necessary to improve the quality of cultivars grown, and address the other production constraints in order that the potential of pigeonpea in Uganda is realized. Future research will therefore concentrate on:

- Field assessment of production problems in different agroecological and socio-economic environments, with a view to designing research that is appropriate for each farming system
- Introduction, collection, and evaluation of germplasm from ICRISAT, the International Institute of Tropical Agriculture (IITA), and various national programs. The emphasis will be on identification and advancement of high-yielding, good quality, short-duration cultivars
- Development of suitable production technologies that fit into the existing cropping system
- Enhancement of collaboration with international research institutions, national programs, extension agents, and farmers.

During the recently conducted research priority setting exercise, pigeonpea was classified as a high-priority research crop, especially for northern and northeastern Uganda. The Agricultural Policy Committee has estimated that pigeonpea research has a fairly good chance of success, and that successful research would substantially increase the demand for pigeonpea.

ICRISAT's Research Agenda on Pigeonpea in Southern and Eastern Africa

Laxman Singh, M V Reddy, T G Shanower, Y S Chauhan, and C Johansen[1]

The southern and eastern Africa (SEA) region is, after the Indian subcontinent, the world's most important ecoregion for pigeonpea production. Pigeonpea is produced in this region under diverse conditions. Cropping systems, a variety of biotic and abiotic constraints, consideration of multiple uses, and preferences (for certain grain types or for fresh green peas/pods, etc.), all impact differentially on the stable production and productivity of pigeonpea. These considerations led to the intensification of research in SEA in the early 1990s, with funding support from the African Development Bank.

Simultaneously, in the early 1990s, ICRISAT initiated a reorganization of its research agenda and management structure, targeting its work at broadly defined production systems in consultation with its partners in the national agricultural research systems (NARS).

This paper describes the process of research project development in general, ICRISAT's proposed pigeonpea research agenda, and specifically those components that impact on pigeonpea research and development in SEA.

Project development at ICRISAT

The important considerations in the development of research projects were: multidisciplinary team-work, focus on production systems, prioritization of activities, a clear indication of outputs or milestones, a time-bound framework, impact orientation, consultation and collaboration with NARS in all phases of planning and research, and the inclusion of environmental, sustainability, and gender issues. ICRISAT's medium term plan (1994-98) was the basis for research focus, prioritization, and allocation of human and financial resources.

Multidisciplinary project planning teams were constituted and mandated to develop research project proposals following the above guidelines. Twenty-three Institute-wide research projects were developed, one of them being a single-commodity project to cover ICRISAT's pigeonpea improvement research. Pigeonpea also figures in the four integrated systems projects (ISPs), where the focus is on how multiple-commodity agricultural systems function and how they can be improved (with pigeonpea being a component of such systems).

Once a project is approved, it will be managed and implemented by a project team consisting of a Project Team Leader and other scientists. The financial, physical, and human resources required to implement the project will be at the disposal of the

1. ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

team, which will develop a workplan and reporting procedures. Thus, along with accountability and responsibility, authority has also been devolved.

We briefly described the process of project development to highlight a few aspects that may be relevant to NARS, some of which are also undergoing reorganization. They are:

- Plan within available resources (human, physical, and financial) and set priorities
- Clearly identify research approach and methodology, e.g., adaptive and on-farm for effective and rapid technology transfer
- Establish clear-cut linkages with Agriculture Ministries, developmental agencies, international agricultural research institutes (IARCs), marketing and processing agencies, etc. These linkages should be effective, and not exist only on paper
- Ensure that strategic on-station (multidisciplinary) research reflects needs and opportunities; linkages with IARCs and mentor institutions will avoid duplication of work
- Make resources available to the Project Team Leader with responsibility and due authority, so that accountability cannot be sidetracked (if the budget is not controlled by the Team Leader, accountability can be escaped on the pretext of non-availability of resources)
- Always set milestones and relate them to impact on farmers and farming systems; periodically assess whether milestones are being reached.

Table 1. Areas of pigeonpea research focus at ICRISAT.

	Subprojects	Activities
1.	Integrated pest and disease management (IPM/IDM). Pests-*Helicoverpa,* podfly, *Maruca.* Diseases-wilt, sterility mosaic, cercospora leaf spot, phytophthora blight, nematodes.	Host-plant resistance Biotechnology (transformation) Mechanisms of resistance Components and integrated management (chemical, biological, cultural) Introgression from cultivated and wild species
2.	Adaptation to environments and cropping systems	GxE analysis Photothermal responses Drought and waterlogging management Plant ideotypes for durability and higher productivity in different environments.
3.	Stimulated adoption to environments and cropping	On-farm testing of technology and cultivars in target cropping systems and environments
4.	Genetic enhancement for durability and productivity	Cytoplasmic and genetic male sterility for hybrid vigor Plant types for biomass, harvest index, etc. (introgression of wild and cultivated species and diverse germplasm) Cleistogamy, seed purity, seed production and maintenance.

Relevance to SEA

The main areas of pigeonpea research focus at ICRISAT are shown in Table 1. The major emphasis will be on short-duration pigeonpea and, where strategic advantage exists, on medium- and long-duration pigeonpea for multiple uses (e.g., sustainability, crop-livestock systems, and agroforestry). The past achievements and programs have been adequately reviewed by Johansen et al. (1994).

Core support to the Pigeonpea Improvement Project

The activities summarized below will be conducted in SEA in collaboration with NARS and the African Development Bank regional project.

IPM/IDM

To help plan and implement the research program of the regional consultant in entomology:

- Identify key pests and estimate crop losses in different agroecological zones in SEA
- Evaluate landraces and improved germplasm for susceptibility to pests
- Undertake on-station and on-farm pest management trials using 'best-bet' technology
- Write and publish information bulletins on pest management
- Screen for and enhance resistance to wilt, cercospora leaf spot, and nematodes
- Identify races of wilt pathogens *(Fusarium udum).*

Enhanced genetic material

- Introduction and multilocation testing of short-duration cultivars for grain and vegetable use in new cropping systems
- Support to the SEA program for production of pure seed
- Participation in review and planning meetings, joint publications, and joint monitoring of on-farm trials.

Adaptation and sustainability

- Photothermal responses and drought management
- Support in publication and reporting
- Long-term experiments on sustainability.

Utilization and agroprocessing

- Training
- Support to a consultant (program framing) and to a women's group (utilization and processing)

Socioeconomics

- Economics inputs for studies on market, demand, and supply.

Achievements from collaborative research

After several years of varietal testing of short-duration pigeonpea, the NARS have identified specific cultivars for on-farm testing in 1994 (Silim et al. 1994):

Kenya	Kat 60/8, ICPLs 87091, 90028, 90029, and 87 W.
Uganda	ICPL 87091, ICPL 87101, Kat 60/8.
Tanzania	ICPLs 151, 86005, 86012, and 87 W.
Malawi	ICPLs 151, 86012, and 87105.

ICP 9145, a wilt-resistant medium-duration cultivar, has been released in Malawi. A few sources of resistance to wilt in Kenya have been identified (e.g., ICPs 8864, 9145, 9155,10957, and 10960).

Cropping systems, constraints, and insect pest losses in Kenya, and Tanzania have been documented. Some of the constraints to increasing production are briefly discussed below.

Cropping systems. Most cultivars/landraces grown in SEA are of very long duration (6-10 months) and thus invariably suffer from terminal drought. Drought stress also aggravates fusarium wilt incidence in this region. Variable and inadequate population limits yields. This largely occurs due to inadequate seedbed preparation, which is done by hand and/or with limited and inefficient ox-power and implements. Soil fertility management is also inadequate, and *in situ* moisture conservation and/or community water-harvesting systems are non-existent.

Postharvest handling. The crop is threshed by hand. The quality of threshed material is often poor because it contains soil and pebbles. Storage capacity is also inadequate.

Insect pest damage. In Africa, as in South Asia, pod-boring lepidoptera (particularly *Helicoverpa armigera* and *Maruca testulalis),* pod-sucking bugs, and podfly (*Melanagromyza* spp) are the most important insect pests. In Kenya's Central Province, 30-35% pod damage due to pod borer (Lateef 1991) and about 11% damage due to podfly, have been recorded. In contrast, in Coast Province, *Maruca testulalis* caused more than 30% damage. In Tanzania, pod-sucking bugs appear to be more important than any other pest. In Kenya also, in a recent survey in five districts pod-sucking bugs appeared to cause greater damage (up to 62%) than pod borer or podfly. The total seed damage recorded in this survey ranged from 26% to 53%, with pod-sucking bugs accounting for more than podfly (Omanga et al. 1991).

Diseases. Losses due to diseases in Kenya, Tanzania, Zambia, Malawi, and Uganda have been estimated.

Networks, linkages, and training. A NARS pigeonpea network was established, as were linkages with agro-industry and farmers. This set the stage for attracting funding and launching the AfDB regional project. Training activities have been an important facet of the collaborative work. To date, four NARS scientists from the SEA region have been trained at ICRISAT Asia Center: P Omanga, M M Siambi, S M Githiri (all from Kenya), and Grace Chepunghalo (Tanzania). All four conducted work leading to an MSc degree.

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Research Reports

From Multilocational Testing and On-farm Trials to Growing Pigeonpea on Farmers' Fields

P A Omanga[1], S N Silim[2], Laxman Singh[3], and P M Kimani[4]

Introduction

Pigeonpea yields in Kenya are generally low (average 300-500 kg ha*[1]). The low yields are due to a number of factors: lack of agroecologically adapted cultivars, improper crop husbandry, and damage by diseases and insect pests. The crop is grown largely by smallholder farmers in the semi-arid regions for home consumption. The surplus is sold at local markets as dried grain. Pigeonpea is exported, both as *dhal* (15 000 t per year) and as green pods for vegetable use (particularly to Europe).

Research objectives are to increase yields and production in Kenya by developing:

- High-yielding varieties with acceptable food quality and resistance to diseases and insect pests
- Short-, medium-, and long-duration varieties suitable for different agroecological zones
- Agronomy packages for each zone, especially for smallholder farmers.

This paper discusses recent progress made on pigeonpea research in Kenya. Results of multilocational varietal trials, on-farm research, and crop improvement strategies are discussed.

Multilocational varietal trials

Short- and medium-duration breeding lines were evaluated during the short rains of 1993/94, at four locations: Katumani, Kiboko, Kampi-ya-Mawe, and Kabete. Climatic data for these locations are summarized in Table 1. At all locations, the crop suffered from terminal drought which resulted in yield reductions.

Medium-duration yield trial

Through breeding and selection, we have developed medium-duration varieties that flower within 110 days and mature within 160 days. Although these cultivars have

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Table 1. Mean temperature, rainfall, and number of rainy days at the four testing sites in Kenya, 1993/94 cropping season.

Location	Rainfall (mm)	No. of rainy days	Mean temp. (°C)
Katumani, short rains	87.1	8	20.2
Katumani, long rains	32.6	5	18.8
Kampi ya Mawe, short rains	94.6	7	22.1
Kampi ya Mawe, long rains	39.5	3	22.2
Kiboko, short rains	35.0	5	25.3
Kiboko, long rains	26.1	5	24.3
Kabete, short rains	82.0	11	17.2
Kabete, long rains	90.0	12	17.2

shown wide adaptation across different agroecological zones, they perform best at medium altitudes (600-1500 m) with mean temperatures of 23-25°C and bimodal rainfall in the range of 400-1500 mm split over two seasons.

Fifteen promising medium-duration cultivars were tested at three locations, representing different environments. The objective was to identify cultivars with high yield potentials, stable phenology, and acceptable seed size (100-seed mass >12 g) across the environments. The experiment was conducted in a randomized block design replicated four times. The plots consisted of five 5-m long rows, with a spacing of 75 x 50 cm, and 3-4 seeds hill^{-1}, thinned to 2 plants hill-^{1} 2 weeks after emergence. The crop was protected against insect pests at each location. Supplemental irrigation was provided at Kiboko; at other locations the crop was rainfed.

The results are summarized in Table 2. The best yielders were different at different locations (e.g., KO 91 at Katumani, Kat 60/8 at Kiboko). In terms of mean yield across locations, the best performers were Kat 60/8 (1.18 t ha^{1}) and KO 91 (1.13 t ha-^{1}). The highest yields were obtained at Kiboko. During the period, Kiboko received less than 200 mm of rainfall. This high yield was therefore due to supplemental irrigation.

Mean time to flowering was similar at the three locations. However, time to maturity was highest at Katumani; evidently the low temperatures at Katumani extend the flowering-to-maturity period.

Short-duration yield trial

Eighteen short-duration (50-80 days to flower) genotypes were tested at four locations to determine their adaptation to different environments. The experiments were conducted in a randomized complete block design replicated four times. Each plot consisted of four rows 5 m long, spaced at 40 x 10 cm (but 30 x 10 cm at Kabete, where it was expected that cool temperatures would retard growth). Supplemental

Table 2. Time to flowering and seed yield in 15 medium-duration pigeonpea cultivars at three locations in Kenya, 1993/94.

Genotype	Mean days to flowering	Grain yield (t ha*[1]) Katumani	Kampi ya Mawe	Kiboko	Mean
Kat 60/8	89	1.02	0.52	2.00	1.18
KO 91	100	1.25	0.60	1.54	1.13
KO 237	95	0.94	0.76	1.61	1.11
ICP 6927	102	1.20	0.32	1.76	1.10
KZ 69/2	98	0.80	0.67	1.73	1.06
K0 71/3	92	1.02	0.72	1.43	1.05
Tanz 22	93	0.81	0.87	1.46	1.05
ICP 7035	88	0.73	0.79	1.58	1.03
Kat 109	91	0.76	0.74	1.57	1.03
KO109	101	0.85	0.47	1.66	0.99
ICPL 8006	93	0.53	0.45	1.57	0.85
KZ 63	104	0.54	0.58	1.40	0.84
Guj 9	96	0.82	0.29	1.33	0.81
ICP 12734	104	0.70	0.50	1.17	0.79
Tanz 9	99	0.67	0.33	1.70	0.78
Mean		0.84	0.57	1.57	0.99
SE±		0.184	0.135	0.205	0.174
CV (%)		37.8	40.9	22.6	33.7

100-seed mass data: 12.2-14.5 g (13.3 ± 0.45)" at Katumani, 10.0-12.6 (11.5 ± 0.59) at Kampi ya Mawe, 10.4-13.7 (11.6 ±0.37) at Kiboko.

irrigation was provided at Kiboko because rainfall was lower than normal. The crop was protected against insect pests and weeds.

Results are shown in Table 3. At all locations, all varieties were early to flower (58-89 days) and fitted well in the bimodal rainfall pattern common in the pigeonpea-growing regions of Kenya. The results clearly indicate that short-duration cultivars may be adapted to areas with warm temperature and low rainfall, and that it would be possible to obtain two crops per year. The cultivars generally flowered and matured most rapidly at Kiboko. Among the 18 cultivars tested, Kat 60/8 was the slowest to flower and mature in all environments.

Yields were highest at Kiboko (due to supplemental irrigation) and Kabete (due to high plant density). Across locations, the best yielders were ICPLs 87109, 86005, 87105, and 87091. All four were also large-seeded.

Selection for seed size

In Kenya, consumers prefer large seed sizes (which are common in the long-duration landraces). We therefore separated the large and small seeds of each of the promising

Table 3. Grain yield and 100-seed mass in 18 short-duration pigeonpea cultivars a four locations in Kenya, 1993/94.

Genotype	Kampi ya Mawe		Kiboko		Katumani		Kabete	
	100-seed mass (g)	Yield (t ha-^{1})	100-seed mass (g)	Yield (t ha^{-1})	100-seed mass (g)	Yield (t ha^{-1})	100-seed mass (g)	Yield (t ha^{-1})
ICPL 87109	11.7	1.30	10.0	3.73	11.0	0.63	9.7	2.57
ICPL 86005	10.2	1.07	11.6	3.43	12.0	0.88	10.4	2.17
ICPL 87105	9.5	0.64	9.7	2.94	10.9	0.67	10.1	2.37
ICPL 87091	12.7	1.39	10.3	3.02	11.3	0.67	10.4	1.48
ICPL 87 W	11.1	0.72	9.7	3.01	9.4	0.62	9.7	1.87
ICPL 87101	9.4	0.85	10.1	3.11	11.7	0.63	8.8	1.63
ICPL 90029	12.2	1.21	12.1	3.27	12.4	0.70	10.6	1.13
Kat 60/8	13.2	1.47	11.1	2.87	13.4	0.86	9.8	1.11
ICPL 90028	10.3	1.38	11.3	2.51	11.9	0.79	9.9	1.47
ICPL 87115	9.5	1.01	7.5	2.37	8.8	0.76	7.4	1.97
ICPL 87104	10.7	1.15	10.2	2.62	11.1	0.42	9.8	1.48
ICPL 90013	9.5	0.69	7.8	2.93	9.6	0.55	7.4	1.56
ICPL 88034	9.8	1.14	12.5	2.75	12.8	0.56	10.4	1.09
ICPL 90001	9.3	0.92	9.1	2.19	17.1	0.71	9.4	1.84
ICPL 88027	10.2	1.12	9.3	2.42	9.5	0.61	7.9	1.09
ICPL 90050	9.8	1.23	7.3	1.73	8.6	0.91	7.4	1.45
ICPL 90024	8.7	0.80	8.3	1.95	8.7	0.45	7.4	1.57
ICPL 86012	9.0	0.84	9.5	2.12	10.1	0.78	8.7	1.23
Mean	10.4	1.05	9.8	2.72	10.8	0.68	9.2	1.62
SE±	0.38	0.168	0.33	0.249	0.06	0.127	0.40	0.345
CV(%)	6.4	30.1	5.9	15.4	5.6	32.1	7.5	37.0

short-duration cultivars, and sowed them at Kiboko during the 1993/94 cropping season. This was done in order to determine the effect of seed size on phenology, plant height, and grain yield, and to test whether seed size could be maintained in the succeeding generation.

The results (Table 4) indicate that plants from bold-seeded selections give higher grain yields. They also indicate that seed size is maintained in the subsequent generation at a given location. However, these results are tentative and more work is required.

Vegetable pigeonpea

Although pigeonpea is consumed mainly as dried grain boiled with maize, the use of green peas is also common in both urban and rural communities. The consumer

Table 4. Effect of variation in seed size on phenology, plant height, 100-seed mass, and grain yield at Kiboko, Kenya, 1993/94 season.

Genotype	Seed size	Days to Flowering	Days to Maturity	Plant height (cm)	Pods $plant^{-1}$	100-seed mass (g)	Yield ($t\ ha^{-1}$)
Kat 60/8	Large	84	122	138	32	12.0	4.2
	Small	83	122	135	44	11.3	4.2
ICPL 87091	Large	61	102	82	41	11.3	3.5
	Small	63	99	76	31	10.1	2.7
ICPL 90013	Large	58	91	67	41	8.3	2.5
	Small	63	97	63	33	7.5	1.1
ICPL 90028	Large	57	91	39	29	9.1	2.0
	Small	58	93	56	30	8.5	2.0
ICPL 90029	Large	59	92	69	29	11.0	2.3
	Small	60	93	68	30	10.5	2.4
Mean for	Large	64	100	79	35	10.4	2.9
	Small	65	101	80	34	9.6	2.5
SE±	Variety	0.4	0.7	4.6	2.6	0.23	0.20
	Seed size	0.3	0.5	2.9	1.6	0.15	0.13
	Interaction	0.6	1.0	6.4	3.7	0.33	0.29
CV(%)		1.7	1.7	14.1	18.6	5.7	20.6

preference is for large pods. In collaboration with ICRISAT, we have identified some large-podded, medium-duration lines suitable for both local and export markets.

During 1993/94, we evaluated the performance of six medium-duration and one short-duration variety at Kiboko and Kabete to determine their yield potential and pod and seed sizes. The results for Kiboko are presented in Table 5. At Kiboko, green pod yields ranged from 3.08 to 7.78 t $ha-^{1}$. Tanz 9 had the largest seeds, while ICPL 87091 and Gujarat Local produced the highest fresh pod yield. These three varieties also had high shelling percentages. At Kabete, green pod yields ranged from 4.42 to 7.48 t ha^{-1} (main + ratoon). The best yielders were Kat 60/8 (7.29 t ha^{-1} main + 0.19 t $ha-^{1}$ ratoon) and Tanz 9 (6.31 t ha^{-1} main + 1.03 t ha^{*1} ratoon).

On-farm research

The introduction of short-duration, small-seeded cultivars is likely to face resistance because consumers prefer bold, cream-colored seeds. If production is to be increased for local (particularly urban) and export markets, the demand for particular products must be established. The main objective of our on-farm trials was to create awareness that short-duration cultivars can be marketed for both grain (for *dhal,* where seed size and color are not critical) and as green pods (for the export market).

Table 5. Days to 50% flowering, pod and seed size, shelling percentage, and green pod yield of promising vegetable pigeonpeas, Kiboko, Kenya, 1993/94.

Genotype	Days to flowering	Pod size Length (cm)	Pod size Width (cm)	100-green-seed mass (g)	Green pod yield (t ha-[1])	Shelling percentage
ICPL 87091	66	7.6	1.2	21.8	7.59	52.1
Kat 60/8	86	7.3	1.1	24.7	4.76	47.6
Tanz 9	88	7.6	1.2	29.7	6.40	53.1
ICP 6927	95	7.6	1.1	24.1	5.05	53.0
Tanz 22	94	7.4	1.1	20.6	3.08	42.7
ICP 7035	89	6.1	1.0	24.3	6.39	49.5
Gujarat Local	88	6.6	1.0	25.8	7.78	53.4
Mean	84	7.3	1.1	24.2	5.86	50.2
SE±	1.7	0.38	0.07	1.83	0.980	2.20
CV(%)	3.6	9.1	10.9	8.8	29	7.5

During the 1993/94 season, we conducted on-farm trials and field demonstrations in Mtito Andei, Kiboko-Kibwezi, and Makueni in Eastern Province and in Kilifi, Kwale, and Mombasa districts in Coast Province. In Eastern Province, farmers were selected jointly by CARE (a non-governmental organization) and the extension staff. In Coast Province, only extension staff were involved in the selection of farmers.

At Kiboko-Kibwezi and Makueni, farmers were given seed of four promising cultivars, Kat 60/8 and ICPLs 151, 87091, 87109, and 90028. Sowing was done jointly by farmers and researchers between 26 Oct and 2 Nov 1993 on 50-m^2 plots replicated twice. The plots were farmer-managed, although researchers provided advice, especially on spraying.

There was severe drought in the 1993/94 season (only 196 mm rainfall), and all other annual crops failed to produce any yield. However, the short-duration pigeonpea produced some yield at both Kiboko-Kibwezi (ICPL 87091, ICPL 87109) and Makueni (Kat 60/8, ICPL 87109), as shown in Table 6.

The agricultural extension officers arranged for farmers to visit the on-farm trials. The farmers indicated that they wanted to grow Kat 60/8 and ICPL 87109.

In the long rains of 1994 (May-Jun), four short-duration cultivars (ICPLs 87 W, 87091, 87109, and 90028) were sown in Kwale, Kilifi, and Mombasa districts in Coast Province. In each district, the seeds were sown on five farms in different agroecological zones. The farmers were selected by the extension staff and most had had previous interactions with them. We are mainly concerned about farmers' reactions to the cultivars and their yield potential. At the time of writing, we had not received any data.

Table 6. Days to 50% flowering (DF) and grain yield of four promising short-duration cultivars in on-farm trials at two locations in Kenya, 1993/94.

	Kat 60/8		ICPL 87091		ICPL 87109		ICPL 90028	
Location	DF	Yield ($t\ ha^{-1}$)	DF	Yield (t ha-1)	DF	Yield (t ha-*)	DF	Yield ($t\ ha^{-1}$)
Kiboko-Kibwezi area[1]	86	0.06	63	0.54	61	0.68	56	0.51
Makueni[2]	90	0.77	83	0.62	77	0.51	68	0.42

1. Mean from 4 farmers' fields.
2. Mean from 6 farmers' fields.

Short-duration cultivars under irrigation

Seed of two promising short-duration cultivars, Kat 60/8 and ICPL 87091, was distributed to some farmers in the irrigation schemes in Makindu, Kibwezi, and Mtito Andei. These schemes specialize in growing vegetables for both local and export markets, using canal irrigation. Our objective was to investigate the potential of green pigeonpea pods for export.

Each farmer was given sufficient seed to sow 125 m^2 of each cultivar in Kibwezi and Mtito Andei, and 0.5 ha in Makindu. For both cultivars, multiple picking was common. For example, the picking of green pods of Kat 60/8 started in Feb and continued till Oct, provided the crop was irrigated. The total area sown was just over 1 ha of ICPL 87091, and 875 m^2 of Kat 60/8. The production from this area was 421 kg of dried seed and 1404 kg of green pods of ICPL 87091, and 511 kg of seed and 1050 kg of green pods of Kat 60/8.

These estimates are for green pods sold for export; the quantities consumed at home were not recorded. The pods were packed in 5-kg cartons that were sold at KS 80-120 depending on supply. One farmer at Makindu earned a net profit of KS 10125 from 0.5 ha of land. His total expenses were KS 4300, while he sold 520 kg of green peas @ KS 20 kg^{-1} and 115 kg of grain @ KS 35 kg^{-1}, earning a total revenue of KS 14 425. Several farmers have approached the 'demonstration' farmers with requests for seed, and some have sown these cultivars in Jun-Jul under irrigation.

Pigeonpea Pathology Research in Kenya

W A Songa[1], S B King[2], and P A Omanga[1]

Introduction

Pigeonpea (*Cajanus cajari)* is an important grain legume in the semi-arid tropics; in Kenya, it is the most important pulse crop after beans. One of the constraints to the production of pigeonpea is disease.

The major diseases of pigeonpea in Kenya (in descending order of importance) are fusarium wilt *[Fusarium udum* Butler), cercospora leaf spot *[Cercospora cajani* Hennings = perfect stage *Mycovelosiella cajani* (Henn.) Rangel ex Trotter], and powdery mildew *[Oidiopsis taurica* (Lev.) Salmon] (Songa and King 1994). Of the three diseases, fusarium wilt and cercospora leaf spot cause yield losses of economic concern. Plant losses of more than 10% due to wilt are common (Kannaiyan et al. 1984, Songa 1991). At higher altitudes (1200-1700 m) losses of up to 80% due to cercospora leaf spot have been reported (Onim 1980). These two diseases are currently receiving research priority with emphasis on host-plant resistance.

This paper describes screening trials conducted during the 1993/94 season to identify pigeonpea genotypes with resistance to these two important diseases.

Screening for wilt resistance at Kiboko

Materials and methods. Work was continued on the establishment of a sick plot at Kiboko for screening pigeonpea for resistance to fusarium wilt. The plot was infested with F. *udum* by adding chopped, diseased stem tissue to furrows at the time of sowing. Inoculum for the sick plot was obtained from farmers' fields near Kiboko (between the towns of Sultan Hamud and Emali) and from wilted plants at the Kiboko Research Station.

Inoculum was first added to a portion of the plot during the 1992/93 short rains, and the area was expanded to about 0.15 ha in 1993/94. Only susceptible materials were sown in 1992/93, but three nurseries of short duration (18 lines), medium duration (15 lines), and long duration (12 lines) were grown and evaluated for their reaction to wilt during 1993/94. Plots were evaluated for wilt incidence several times during the season, including at maturity.

The susceptible control, ICP 2376, was sown throughout the nursery. Half of the ICP 2376 control plots had additional inoculum added to the 1993/94 sowing furrow;

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2. ICRISAT, P O Box 39063, Nairobi, Kenya.

Table 1. Reaction of 18 short-duration pigeonpea lines to fusarium wilt in the wilt sick plot, Kiboko, Kenya, short rains 1993/94.

Genotype	Days to 50% flowering[1]	Total plant stand after thinning	Wilt incidence (%)[1]		
			60 DAS	75 DAS	96 DAS
ICPL 87104	58	69	15.5	19.9	27.3
ICPL 90013	65	88	16.7	22.3	30.1
ICPL 87105	61	85	18.9	22.5	32.9
ICPL 86012	58	95	12.4	16.8	37.4
ICPL 83024	59	83	15.8	22.3	38.3
ICPL 90029	61	99	23.7	28.4	41.1
ICPL 87101	61	89	29.3	34.4	48.1
ICPL 87109	64	71	17.9	29.2	49.4
ICPL 87091	63	97	29.1	40.8	52.2
ICPL 90024	59	95	31.9	44.4	56.6
ICPL 87115	62	90	29.9	44.4	56.7
ICPL 88022	60	98	33.8	44.7	57.2
ICPL 90028	59	102	25.2	39.5	58.5
ICPL 90050	62	100	34.0	44.0	60.3
ICPL 86005	61	89	37.4	44.2	60.7
Kat 60/8	82	102	37.6	47.7	63.1
ICPL 90001	62	96	35.5	46.8	66.1
ICPL 87 W	59	73	39.4	52.7	68.9
ICP 2376 (susceptible control)[2]	107	11	21.3	34.8	45.3
ICP 2376 (susceptible control)	109	12	35.5	51.8	59.7
Mean	65.9	82.5	27.5	36.4	50.5
SE±	0.69	4.69	5.26	5.81	6.93
CV (%)	1.8	9.8	33.7	27.6	23.7

1. Average of 3 replications. Percentage wilt was recorded at 60, 75, and 96 days after sowing (DAS), when most entries (except Kat 60/8 and ICP 2376) had reached flowering, podding, and maturity, respectively.
2. Diseased stem tissue not added to the sowing furrows. Diseased stem tissue was added in 1993/94 to sowing furrows of all other entries, including the other ICP 2376 susceptible control.

the remaining half had no additional inoculum, relying solely on inoculum remaining in the soil from the 1992/93 sowing.

Results and discussion. All test entries in the short-duration nursery (Table 1) flowered in 58-65 days after emergence except for Kat 60/8 (82 days) and the susceptible control, ICP 2376. Significant differences were found among entries for susceptibility to wilt, with ICPLs 87104, 90013, and 87105 being the most resistant. Wilt incidence in all entries increased progressively from flowering till maturity, with final wilt percentages ranging from 27.3% to 68.9% for the 18 test entries.

We were rather surprised to find such high levels of susceptibility in short-duration materials in this test, since in India wilt generally develops to only a very low level in short-duration materials. We believe these high disease levels may have been influ- enced by the environment at Kiboko, possibly warmer temperatures and greater

Table 2. Reaction of 15 medium-duration pigeonpea lines to fusarium wilt in the wilt sick plot Kiboko, Kenya, short rains 1993/94.

Genotype	Days to 50% flowering[1]	Total plant stand after thinning	Percentage wilt at 177 DAS[1]
BDN1	90	31	33
ICP 87051	134	31	9.6
LRG30	103	32	34.4
ICP 7035	98	33	42.6
Kat 60/8	90	28	44.8
KO 109	100	33	48.2
ICP 6927	109	30	50.0
ICP 12734	121	28	53.1
ICP 8006	95	30	54.0
Kat 109	116	30	56.7
Kat 96/9	125	31	65.4
ICP 9145	129	31	71.0
Tanzania 9	100	30	74.1
Tanzania 22	115	29	76.5
Kat 50/3	107	32	87.5
ICP 2376 (susceptible control)[2]	114	21	80.6
ICP 2376 (susceptible control)	113	27	95.8
Mean	109.2	29.8	55.7
SE±	2.1	1.1	10.3
CV(%)	2.7	10.8	26.0

1. Average of 2 replications. Wilt recorded at the time most entries had reached maturity. DAS = days after sowing.
2. Diseased stem tissue not added to the sowing furrows. Diseased stem tissue was added in 1993/94 to sowing furrows of ail other entires, including the other ICP 2376 susceptible control.

stress due to low soil moisture, or they may reflect pathogenic differences between populations of F. *udum* in Kenya and India, with the Kiboko population possibly being more aggressive at earlier stages of pigeonpea development. The susceptible control in this test, ICP 2376, had lower than expected wilt incidence (45.3-59.7%), probably because the final wilt evaluations were made several weeks before this line had reached maturity.

These results, together with other observations, emphasize the necessity of screening for wilt resistance in the eastern and southern Africa region, and particularly in those countries where lines are being identified for use by farmers.

In the medium-duration nursery, time to 50% flowering ranged from 90 to 134 days, and percentage of infection at or near maturity ranged from 3.3 to 87.5%, with significant differences among entries for wilt (Table 2). The susceptible control ICP 2376 had 80.6% (no inoculum added to soil) and 95.8% (additional inoculum added to soil) wilted plants at maturity. In view of the very high levels of wilt in some of the entries, it is encouraging to note the relatively low levels in others, especially BDN 1 (only 3.3% wilt) and ICP 87051 (9.6% wilt). It is worth noting that ICP 9145, which is wilt-resistant at Katumani, ICRISAT Asia Center (India), and Malawi, where it is being grown by farmers, is highly susceptible (71% wilt) at Kiboko.

Among the 12 test entries in the long-duration nursery, time to flowering ranged from 129 to 222 days (Table 3). Percentage infection ranged from 34.5 to 76.2%, with statistically significant differences for reaction to wilt among the entries. The ICP 2376 controls had 80.6% wilt on plots that relied on inoculum only from the previous season, and 95.8% wilt on plots to which additional inoculum had been added in 1993/94. This suggests that a high level of inoculum had been retained in the soil from the previous season.

We harvested seed from symptom-free plants in all these nurseries, and plan to compare their reactions to those from remnant seed next season in the wilt nursery, to determine if there is residual variability within lines for wilt resistance, a situation that could possibly be exploited to increase wilt resistance in elite materials.

Table 3. Reaction of 12 long-duration pigeonpea lines to fusarium wilt in the wilt sick plot, Kiboko, Kenya, short rains 1993/94.

Genotype	Days to 50% flowering[1]	Plant stand after thinning	Percentage wilt at 205 DAS[1]
ICP 13076	222.0	26	34.5
Kat 590	195.5	24	41.7
Kat 777	189.5	24	45.8
Kat 66	195.5	26	51.3
10 Babati	-	26	52.3
ICP 9150	210.0	24	52.7
Kat 81/3/3	206.0	26	57.5
Kat 2	199.0	24	62.5
ICP 13510	165.0	26	65.9
ICP 13082	207.0	22	68.3
16 Kenya	193.5	24	74.8
Farmer 8	129.0	24	76.2
ICP 2376 (susceptible control)[2]	114.0	26	80.6
ICP 2376 (susceptible control)	113.5	20	95.8
Mean	188.5	12.49	61.5
SE±	4.21	0.37	4.2
CV(%)	8.36	11.2	25.9

1. Average of 2 replications. Wilt recorded at the time most entries reached physiological maturity. DAS = days after sowing.
2. Diseased stem tissue not added to the sowing furrows. Diseased stem tissue was added in 1993/94 to sowing furrows of all other entries, including the other ICP 2376 susceptible control.

Screening for wilt resistance at Katumani

Materials and methods. A total of 130 lines consisting of improved and introduced medium-duration material (150-180 days) were screened in 1993/94 in a wilt sick plot established in 1981. The sick plot was established by incorporating debris of chopped, wilted plants collected from the major pigeonpea-growing areas of eastern Kenya. This sick plot has a high level of inoculum; however, due to station development activities the plot cannot be expanded to accomodate more material. For this reason, a larger plot has been developed at a new site within the station.

The test material was sown in two replicates of single rows of 4 m length. Susceptible controls, Kat 777 (a high-yielding but susceptible local, improved variety) and ICP 2376, were sown alternately in every fifth row to ascertain the inoculum uniformity in the plot. The data collected included number of emerged plants and number of wilted plants over time until maturity. Diseased samples were randomly selected for laboratory confirmation of the presence of F. *udum.*

Seed from symptom-free plants was harvested with the intention of comparing their reactions with those of remnant seed of the specific genotypes, to determine if there is residual variability within lines for resistance to wilt.

Results and discussion. Wilt was observed from 15 days onward after emergence, but the incidence was much higher from flowering to maturity. Final wilt incidence ranged from 0 to 63.1% (Table 4). High resistance levels were observed in 8 introduced and 13 improved lines. The ICRISAT line ICPL 91047 had the highest wilt incidence of 63.1%, whereas the susceptible controls, Kat 777 and ICP 2376, had wilt incidence of 44.9% and 47.5% respectively (Table 4).

ICP 8863 was among the lines with high resistance; in an earlier study, this genotype gave a resistant reaction to 10 isolates of F. *udum* collected from eastern Kenya (Songa et al. unpublished). This line is also reported to be resistant in India. The line ICP 2376, susceptible in India, had an average wilt incidence of 47.5% compared with 100% usually reported at ICRISAT Asia Center. This observation implies the presence of pathogenic differences between F. *udum* isolates in Kenya and India. However, the reaction of ICP 8863 suggests that resistance to both Kenyan and Indian isolates may be found in some genotypes.

Screening for multiple disease resistance at Katumani

Materials and methods. A larger wilt sick plot of about 0.5 ha has been developed at Katumani to screen for combined resistance to fusarium wilt and cercospora leaf spot. Wilted pigeonpea plants from the old sick plot were used to increase the level of F. *udum* in the plot.

Three varieties with high susceptibility to wilt (ICP 2376, Kat 777, and LRG 30), and one variety susceptible to cercospora leaf spot (E 31/4) were sown in alternate rows in the last three crop seasons starting from the short rains of 1991 (i.e., sown in Oct each year).

Table 4. Pigeonpea lines resistant to fusarium wilt in the sick plot at Katumani, Kenya, 1993/94.

Genotype	Plant stand	Wilt (%)	Genotype	Plant stand	Wilt
Introduced lines			Improved lines		
ICP 8863	20	0.0	Kat 777		
ICPL 89048	33	0.0	(susceptible control)	31	44.9
GPS 3	20	0.0	Kat 15/94	42	1.0
GPS 7	14	0.0	Kat 18/94	18	0.0
GPS 30	17	5.8	Kat 20/94	33	1.8
GPS 33	16	0.0	Kat 217/94	18	2.2
GPS 36	19	3.1	Kat 595/94	40	0.0
GPS 52	19	2.3	Kat 29/94	34	5.4
ICP 2376			Kat 99/94	19	3.4
(susceptible control)	14	47.5	Kat 59/94	23	5.7
ICPL 91047	16	63.1	Kat 231/94	32	5.0
			Kat 603/94	38	4.0
			Kat 122/94	23	3.2
			Kat 248/94	29	4.8
			Kat 158/94	32	1.8

Supplementary irrigation was given twice a week, for two hours each time, in May and Jun; this was to create suitable conditions for the development and spread of cercospora leaf spot. Wilt incidence was assessed as mentioned previously. Cercospora was scored on 100 randomly selected plants of E 31/4, using a scale of 1 to 9 (1 = no symptoms, 9 = severe symptoms, Songa 1991), at the flowering stage in May and Jun, when the disease is most prevalent.

Results. Wilt incidence was observed to increase steadily in the plot (Table 5). ICP 2376 had the highest wilt incidence of 64% in 1993/94. Considering the high wilt levels observed in the susceptible controls in 1993/94, the new wilt sick plot is now ready for use, for screening for resistance to fusarium wilt.

Cercospora leaf spot scores on the susceptible line E 31/4 were 6.5 in 1991/92, 7.8 in 1992/93, and 7.5 in 1993/94. The general high level of susceptibility observed in the 3 years implies that Katumani is a suitable site for screening for resistance to cercospora leaf spot.

The plot is now ready for evaluation for combined resistance to fusarium wilt and cercospora leaf spot.

Table 5. Fusarium wilt incidence in three pigeonpea lines during three crop seasons[1] at the new wilt sick plot, Katumani, Kenya.

	Wilt incidence (%)		
Genotype	1991/92	1992/93	1993/94
Kat 777	38.7	45.2	51.3
ICP 2376	42.9	56.8	64.1
LRG 30	47.3	52.6	57.4

1. Sown in Oct each year

General discussion

Kenya now has sick plots at two sites—Kiboko and Katumani—for testing for wilt resistance. The plots have differences in environment (Kiboko is somewhat warmer than Katumani), and in pathogen population; inoculum for the Kiboko sick plot comes from a geographically more restricted area (Kiboko Research Station and nearby from along the Sultan Hamud-Emali road) than inoculum for the Katumani sick plot (all pigeonpea production areas of Eastern Province). We anticipate that these two sites will complement each other in the evaluation of materials suitable for Kenya.

Testing to date has shown that reaction to wilt can vary considerably between ICRISAT (India) and Africa, between sites within Africa (e.g., Kenya and Malawi), and even between sites within the same country (e.g., Kiboko and Katumani in Kenya). This indicates the need for wilt resistance testing within areas of pigeonpea production. We would like to see the development of wilt sick plots in more countries within the southern and eastern Africa region to reduce the potential danger of relying on possibly inappropriate results obtained in other production areas. There is evidence that pathogenic variability exists in *F. udum,* but these differences have not been well defined for the southern and eastern Africa region. With the development of more sick plots within the region, it will not only become possible to better understand the pathogenic variability of *F. udum* in the region, and between the region and India, but it will also provide information on the adaptation of pigeonpea in southern and eastern Africa.

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Development of Agronomy of Short-duration Pigeonpea

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Introduction

In parts of eastern and southern Africa, pigeonpea is an important component of the traditional farming systems, in which medium- and long-duration landraces are mix-cropped or intercropped with cereals, short-duration legumes, or such other long-duration annuals as cotton (Baldev 1988, Silim et al. 1991). Most of the landraces are grown in drought-prone areas with either unimodal or bimodal rainfall, and may fail to produce grain in years of severe drought, as was the case in parts of Kenya and northern Tanzania in 1993.

Concerted research effort by ICRISAT (Laxman Singh et al. 1990) and national agricultural research centers has resulted in the development of short-duration pigeonpeas that escape drought and permit the growing of two crops a year (Laxman Singh 1991). However, in the eastern and southern Africa region, the agronomy of the short-duration varieties has still to be developed. In existing cropping systems, landraces are grown with little regard for spacing and population. For example, in 1992, seeds of a promising cultivar, Kat 60/8, were given to farmers to grow as a sole crop. Some grew it at wide row spacings (>1 m), and others intercropped it with maize.

The objectives of the study, which is being conducted in Kenya, and will later be expanded to the whole region, are to develop appropriate production packages for short-duration pigeonpea.

Appropriate seeding density

Areas in Kenya with the potential for growing short-duration pigeonpea vary in altitude from sea level to about 2000 m, i.e., from Coast Province through Eastern Province to Rift Valley Province. The temperatures in these areas vary from high to low with increase in altitude (Table 1).

In Eastern and Rift Valley Provinces, the Oct-Feb growing season has higher mean temperatures than the Apr-Aug period. Reports indicate that pigeonpea is extremely sensitive to environmental factors, particularly temperature and photoperiod (Byth et al. 1981, Whiteman et al. 1985); the traits most affected are plant height, phenology,

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Table 1. Long-term mean annual maximum and minimum temperatures at the locations used in the study.

Location	Altitude (m)	Mean temp (°C) Max	Min	Mean	Remarks
Mtwapa	50	30.4	27.4	28.9	High max, high min
Kiboko	980	30.4	16.3	23.3	High max, low min
Kabete	1825	22.3	12.9	17.6	Intermediate max, low min

biomass, and grain yield. The instability in height and size are major constraints to the development of such management practices as appropriate plant density. This study aims at determining the most appropriate seeding density for areas varying in temperature. During the 1992-94 period, we used the most promising short-duration cultivars to determine the appropriate seeding density in three areas where short-duration pigeonpea may be grown, but which vary in temperature (Table 1).

In Oct 1992 and Apr 1993 sowings, the following populations ha-^{1} were used: 133 333, 166 666, 222 222, and 333 333, representing respectively 75, 60, 45, and 30 cm interrow spacings. In Oct 1993 and Apr 1994 sowings were at 153 846,181 818, 222 222, 285 714, and 400 000 plants ha-^{1}, representing respectively 65, 55, 45, 35, and 25 cm spacings. Within-row spacing was 10 cm for all treatments and all sowings.

The results show that on the coast (Mtwapa) and for the Oct sowing at Kiboko, when temperatures are high to moderate and when plants grow taller, optimum density for high grain yield is 222 222 plants ha^{-1}, representing a spacing of 45 x 10 cm (Table 2). When growth is restricted due to low temperatures, as in Kabete and

Table 2. Grain yield (t ha^{1}) of short-duration pigeonpea as affected by seeding density at two locations in Kenya, where temperatures during the growing season were high.

Seeding density (D) (plants ha^{-1})	Kiboko, Oct 1992 sowing, Varieties (V): Kat 60/8	ICPL 87109	ICPL 87 W	Mean	Mtwapa, Apr 1993 sowing, Varieties 0 0: ICPL 90028	ICPL 87109	ICPL 87 W	Mean
133 333	1.60	1.40	1.60	1.53	1.36	1.62	1.00	1.33
166 666	1.61	1.61	1.35	1.52	1.76	1.84	1.51	1.70
222 222	2.33	1.92	1.45	1.90	1.78	2.25	2.40	2.14
333 333	1.98	1.71	1.90	1.86	1.40	2.37	2.19	1.99
Mean	1.95	1.67	1.57		1.58	1.95	1.77	
SE±	D = 0.121, V= 0.136, DxV = 0.272				D=0.167,V=0.148, D xV=0.296			
CV(%)	26.7				29.0			

in the Apr sowing at Kiboko, then optimum density is higher, about 285 714 plants ha^{-1}, representing a spacing of 35 x 10 cm (Table 3). These results are in agreement with those reported by Saxena (1981) and Silim et al. (1990) in lentils, that when conditions restrict vegetative growth, larger population densities result in significant gain.

In this study, Kabete and Apr sowings at Kiboko grew under relatively low to intermediate temperatures, whereas at Mtwapa and Oct sowing at Kiboko growth occurred under higher mean temperatures. Low to intermediate temperatures at Kabete and for Apr sowing at Kiboko most probably restricted growth, and higher populations were required to optimize yield. This suggests that in areas with low to intermediate temperatures, higher seeding densities should be used.

Intercropping short-duration pigeonpea with maize

We have mentioned earlier that farmers routinely intercrop or mix-crop pigeonpea with cereals, long-duration annuals, and other short-duration legumes (Baldev 1988, Silim et al. 1991). They also intercrop maize with such short-duration legumes as beans and cowpea (Fisher 1977a, b). As indicated earlier, when farmers were given seeds of short-duration pigeonpea together with the production package, a large proportion intercropped with maize. Short-duration pigeonpea is thus likely to find acceptance in areas where maize is currently intercropped with short-duration legumes. We therefore conducted a trial at Kiboko in eastern Kenya using a promising short-duration pigeonpea cultivar intercropped with an adapted maize cultivar to determine the most appropriate density. Different row arrangements and spacings were used to determine the best combination.

Table 3. Grain yield (t ha^{-1}) of promising short-duration pigeonpea as affected by seeding density at two locations in Kenya, where temperatures during the growing season were low to moderate.

Seeding density (D) (plants ha^{-1})	Kabete, Oct 1993 sowing			Kiboko, Apr 1994 sowing		
	Varieties (V)			Varieties (V)		
	Kat 60/8	ICPL 87091	Mean	Kat 60/8	ICPL 87091	Mean
153 846	1.83	1.69	1.76	1.69	2.23	1.96
181 818	2.29	1.93	2.11	2.12	1.82	1.97
222 222	2.64	1.91	2.28	2.17	2.37	2.27
285 714	2.69	1.95	2.32	2.49	2.25	2.37
400 000	2.27	2.20	2.23	2.32	2.25	2.28
Mean	2.34	1.94	2.14	2.16	2.18	
SE±	D = 0.220, V = 0.073, DxV = 0.163			D = 0.150, V = 0.095, DxV=0.213		
CV(%)	13.3			18.6		

Results are shown in Table 4. Grain yields of pigeonpea ranged from 0.79 t ha^{-1} in T_8 to 3.04 t ha^{-1} in T_2; and for maize from 2.22 in T_5 to 3.57 t ha^{-1} in T_1. The land equivalent ratio (LER) ranged from 1.10 in T_5 to 1.30 in T_9.

In eastern Kenya, maize is normally regarded as the major component of the cropping system. The farmer's main objective is to maintain maize yield as close as possible to sole yield, while obtaining additional yield from the companion crop (Silim et al. 1991). The results of the study show that if farmers plan to intercrop short-duration pigeonpea with maize, then the best combination is paired rows of maize (40 cm row spacing) with two rows of pigeonpea. This treatment provides maize grain yield at near sole yield level, gives high pigeonpea yield, and gives the highest LER (T_9, Table 4). Of course, this was the first year of study and was conducted under assured moisture supply. In the coming cropping season, the trial will be conducted at different locations under rainfed conditions before recommendations are made to farmers.

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Table 4. Intercropping short-duration pigeonpea, ICPL 87091, and maize, Makueni composite, at Kiboko, Kenya, long rains 1994.

	Treatment	Pigeonpea Phenology DF[1]	Pigeonpea Phenology DM	Pigeonpea Yield (t ha^{-1})	Pigeonpea LER	Maize Phenology DF	Maize Phenology DM	Maize Yield (t ha^{-1})	Maize LER	Total LER
T_1	Sole maize (M), 80 cm spacing	-	-	-	-	40	56	3.57	1.00	1.00
T_2	Sole pigeonpea (PP), 40 cm spacing	63	105	3.04	1.00	-	-	-	-	1.00
T_3	Intercrop M and PP, 1:1 ratio	69	116	1.31	0.43	41	90	2.81	0.79	1.22
T_4	Intercrop M and PP, 1:2 ratio	66	114	1.58	0.52	40	88	2.86	0.63	1.15
T_5	Intercrop M and PP, 2:4 ratio	65	108	1.47	0.48	40	87	2.22	0.62	1.10
T_6	Intercrop M and PP, 2:2 ratio	68	113	1.10	0.36	40	87	2.76	0.77	1.13
T_7	Intercrop M and PP, 2:1 ratio	68	115	0.84	0.28	40	90	3.30	0.93	1.21
T_8	Intercrop, paired rows M (40 cm spacing) and 1 row PP	66	117	0.79	0.26	40	88	3.42	0.96	1.16
T_9	Intercrop, paired rows M (40 cm spacing) and 2 rows PP	66	113	1.38	0.45	40	88	3.03	0.85	1.30
T_{10}	Intercrop, paired rows M (40 cm spacing) and 3 rows PP	66	111	1.76	0.56	41	87	2.33	0.65	1.21
	Mean	67	113	1.48		40	88	2.86		
	SE ±	0.7	1.0	0.146		0.6	0.8	0.180		
	CV (%)	1.9	1.6	17.1		2.6	1.5	11.0		

1. DF/DM = days to flowering/maturity

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Use of the Kenya Transect for Selecting and Targeting Adapted Cultivars to Appropriate Production Systems

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Introduction

Pigeonpea production systems in eastern and southern Africa are based on intercropping or mixed cropping of indeterminate, unimproved long- and medium-duration landraces with cereals, short-duration legumes, or with such other long-duration annuals as cotton, cassava, and castor (Laxman Singh 1991). More recently, long-duration pigeonpea varieties have been used in agroforestry (Silim et al. 1991). In these traditional cropping systems, pigeonpea often suffers from abiotic (intermittent and terminal drought) and biotic (pests and diseases) stresses.

The crop is grown mainly for its grain, which contains between 17 and 28% protein and is an important diet supplement for subsistence farmers, who eat mainly low-protein cereals and root crops (Jambunathan and Singh 1981). Pigeonpea helps improve soil fertility, thus contributing to sustainability, through atmospheric N-fixation, nutrient cycling, and leaf fall (Sheldrake and Narayanan 1979).

The traditional landraces in eastern and southern Africa are grown at altitudes varying from sea level to about 2000 m. However, pigeonpea is extremely sensitive to temperature and photoperiod, with plant height, vegetative biomass, phenology, and grain yield being the most affected (Byth et al. 1981, Whiteman et al. 1985). This sensitivity is a major constraint to the development of stable and predictable management practices, production systems, and varieties (Whiteman et al. 1985). Instability in height and vegetative biomass make management practices (e.g., insecticide spraying, determining plant density) and harvesting difficult. Sensitivity in phenology, if it leads to a delay in maturity, may interfere with a well developed cropping sequence when the succeeding crop is sown soon after pigeonpea is harvested. A delay in phenology may also reduce yield in areas where rainfall duration is short and where the crop depends on residual moisture. In areas with bimodal rainfall, such as Kenya, acceleration in phenology may result in reproductive growth occurring between the two rainfall periods; the crop would thus suffer from drought stress. Similarly, where there is accelerated phenology, reproductive growth may coincide with a period of high pest incidence (Wallis et al. 1981).

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Concerted research effort by ICRISAT has resulted in the development of extra short and short-duration varieties that escape drought and are relatively insensitive to photoperiod, thus increasing the flexibility of pigeonpea cultivation and facilitating its use in different cropping systems (Nene 1991). However, these extra short and short-duration varieties are still sensitive to temperature. For example, our attempts to introduce the crop in the highlands of Kenya in rotation with wheat have not been successful because at low temperature, there was delayed phenology and stunted growth.

Although pigeonpea is an important source of protein in the dry areas of eastern and southern Africa and has a high potential as a commercial crop, there has been no continuous, concerted research effort. We need, therefore, to intensify pigeonpea research in Africa because there are still major problems to be solved. Adaptation of the crop in the region is different from that in the Indian subcontinent. Medium- and long-duration breeding lines developed at ICRISAT Asia Center, India, have shown high potential there, but have often performed poorly and are not well adapted in eastern and southern Africa. Most of the lines developed in India have small, brown seeds, whereas large, cream or speckled seeds are preferred in Africa.

In eastern and southern Africa, pigeonpea is grown at altitudes varying from sea level to about 1800 m in three major production systems, all of which are found in Kenya:

- Semi-arid, intermediate season (100-125 days) sorghum/maize/rangeland
- Intermediate season (125-150 days) sorghum/maize/finger millet/legumes
- Sub-humid lowland with mixed rice/maize/groundnut/pigeonpea/sorghum.

In stressful environments such as those in which pigeonpea is often grown, if phenology can be predicted, then it would be possible to target and fit genotypes well into different production and farming systems. This would enable appropriate genotypes to be grown, exploiting environmental resources to the best benefit of the crop and minimizing the effects of seasonal constraints (Byth et al. 1981).

The Kenya transect, which is near the equator (1°15' to 4°25' S) and which we refer to as a *field laboratory,* varies from 0 to over 1800 m in altitude. This offers a unique opportunity for screening genotypes for adaptation to temperature (which is lower at high altitude) with little variation in daylength. Variation in photoperiod for screening medium- and long-duration cultivars is achieved by extending daylength using artificial lighting. Four locations that vary in temperature are being used for the study (Table 1).

Objectives

For extra short and short-duration pigeonpea the objectives are to:

- Understand the influence of temperature on phenology, height, biomass, and grain yield
- Determine whether there is variability among cultivars for adaptation to temperature, particularly at sub-optimal levels, so that lines adapted to low temperatures

Table 1. Long-term mean annual maximum and minimum temperatures at locations used in the study, Kenya.

		Mean temp (°C)			
Location	Altitude (m)	Max	Min	Mean	Remarks
Mombasa	50	30.4	27.4	28.9	High max, high min
Kiboko	980	30.4	16.3	23.3	High max, moderate nights
Kiboko (Apr-Jul)[1]		28.7	15.3	22.0	High max, low nights
Katumani	1560	24.7	13.9	19.3	Intermediate max, low min
Kabete	1825	22.3	12.9	17.6	Low max, low min

1. Data for 1994 only.

are targeted at high-altitude areas where cereals are currently continuously cropped, e.g., wheat-growing areas in Kenya

- Determine whether the Kenya transect is a useful tool for screening pigeonpea cultivars and defining their adaptation to temperature, to permit targeting at appropriate production systems in the region. This would economize on the number of genotypes required to be tested by the NARS.

For medium- and long-duration pigeonpea the objectives are to:

- Understand the influence of temperature and photoperiod on phenology, height, biomass, and grain yield
- Determine whether genetic variability exists among cultivars from different environments in adaptation to temperature and photoperiod
- Determine whether the Kenya transect is a useful tool for screening pigeonpea cultivars for their adaptation to temperature and photoperiod so as to best target them to the most suitable environments.

For all maturity duration groups, major selection criteria (in addition to phenological response) are high grain yield, large seed size, and cream seed color.

Short- and extra short duration pigeonpea

A nursery consisting of 121 lines of determinate (DT) and non-determinate (NDT) extra short and short-duration pigeonpea from ICRISAT Asia Center and the Kenyan national program were sown between late Oct and early Nov 1992 at Kiboko, Katumani, and Kabete; and in Apr 1993 at Mombasa. In Oct 1993 and Apr 1994 another set of 64 lines was tested at Kiboko, Katumani, and Kabete. Each treatment plot consisted of two rows 5 m long. Records were kept for daily maximum and minimum temperatures, plant height at flowering, days to flowering and maturity, grain yield, and 100-seed mass.

Phenology. Days to flowering and maturity were fewest for the Nov sowing at Kiboko. At Mombasa, where mean temperature was high during the growing season, phenology was delayed. Similarly, phenology was delayed at Katumani and Kabete, where mean temperatures were low (Tables 1-3). The cultivars developed by the Kenyan national program were of later phenology than those developed by ICRISAT. The results show that the delay in phenology associated with low temperatures may interfere with the cropping sequence in areas with bimodal rainfall, e.g., high-elevation (>1600 m) areas of Kenya.

Table 2. Effect of temperature on phenology, height, 100-seed mass, and grain yield in 121 extra short and short-duration pigeonpea genotypes, Kenya, 1992/93.

Location	Days;to		Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{-1})
	Flowering	Maturity			
Mombasa[1]					
Range	66-117	110-167	50-217		1.00-3.10
Mean	80	122	91		1.77
Kiboko[2]					
Range	52-110	95-158	36-249	6.9-13.3	0.83-4.33
Mean	60	106	77	10.0	2.18
Katumani[3]					
Range	66-137	119-179	34-153	8.8-15.8	
Mean	76	128	58	11.2	
Kabete[4]					
Range	83-116	136-178	30-124	9.1-15.1	0.91-4.93
Mean	90	152	57	11.2	2.14

Temperature: 1 = high mean, 2 = high max, moderate min, 3 = intermediate max, low min, 4 = low max, low min

Table 3. Effect of temperature on phenology, height, 100-seed mass, and grain yield in 64 short-duration pigeonpea genotypes sown in Nov 1993 and Apr 1994, Kenya.

Location	Days to		Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{1})
	Flowering	Maturity			
Kiboko[1], Apr 1993 sowing					
Range	55-73	82-141	46-134	6.3-11.6	1.07-2.20
Mean	61	95	74	7.7	1.50
Kiboko[1], Apr 1994 sowing					
Range	60-71	105-158	44-94	8.2-12.9	1.36-3.56
Mean	63	110	63	9.7	2.41
Katumani[2], Nov 1993 sowing					
Range	79-99	127-163	33-69	7.3-14.1	0.19-1.97
Mean	85	137	52	9.8	1.08
Kabete[3], Nov 1993 sowing					
Range	76-94	116-138	40-91	7.4-12.9	1.22-3.15
Mean	80	122	62	9.4	2.16

Temperatures: 1 = high max, intermediate min, 2 = intermediate max, low min, 3 = low max, low min

To determine the response of individual genotypes to temperature, we used the general model of flowering responses to photothermal conditions in annual crops in terms of rate of progress towards flowering (1/f) (Summerfield et al. 1991), using only the thermal component because short-duration cultivars are relatively insensitive to photoperiod:

$1/f = a + bT$, where f is the number of days to first flower, T is mean preflowering temperature (°C), and a and b are cultivar-specific constants. The results show that among the lines tested, optimum temperature (for most rapid flowering) ranged from 19.0 to 23.9°C. Since our study focused on pigeonpea suitable for rotation with wheat at high elevations, we selected cultivars that showed stability in phenology at sub-optimal temperatures. These cultivars were: KO 71/3, KO 91, KO 109, KZ 63, KZ 69/2, Kat 50/3, Kat 60/8, and ICPLs 87 W, 83016, 86005, 86023, 87091, 87109, 89030, 90013, 90037, and 91009 (Table 4). The first seven lines were developed in Kenya at high elevation, hence their stability. They are, however, late in phenology and would not fit into the cropping sequence in rotation with wheat in Kenya.

Plant height. Reduction in temperature through increase in altitude reduced crop height—plants were shorter at low temperatures (Table 2). ICPLs 87091, 87109, 90001, and 95004 showed relative stability in height in all environments, while cultivars from the Kenyan national program showed the least stability, growing to 2.5 m at high temperatures.

Grain yield. Grain yields were not adversely affected by variation in mean temperatures (Tables 2 and 3). Location mean yields were 1.77 t ha^{-1} for Mombasa, 2.18 t ha^{-1} for Kiboko, and 2.14 t ha^{-1} for Kabete (Table 2). Cultivars adapted to various altitude/temperature conditions are listed in Table 5. The criteria used while selecting a cultivar for release include acceptable height, phenology that would permit fitting into a cropping sequence, high grain yield, and acceptable grain color and size. ICRISAT has been supplying nurseries to collaborators in the region for testing. The Kenyan national program has identified Kat 60/8, ICPL 87091, and ICPL 87109 for on-farm trials. Except for Kat 60/8 (identified specifically for medium to high elevations), the other cultivars were selected for cultivation at a wide range of altitudes, from low to high. Selections made by the national program through multilocational testing agree with ours, which were done using the transect. The major constraint at high altitude is delayed phenology. In Tanzania, ICPL 86005 has consistently performed well at low to intermediate elevations and is now being tested on-farm. The same cultivar was also identified, using the Kenya transect, as adapted to low to intermediate elevations. In multilocational trials conducted in Uganda at about 1000 m altitude, Kat 60/8 and ICPLs 86005, 87091, 87101, 87109, and 90029 were identified as the best yielders. A study using the Kenya transect identified the same cultivars as among the best adapted and highest-yielding at intermediate elevations. These results confirm that the Kenya transect is an effective tool for screening cultivars and identifying areas in eastern Africa where they are best adapted. We will therefore continue using the transect to test introductions and new breeding lines to target cultivars to appropriate production systems.

Table 4. Extra short and short-duration cultivars suitable for different environments in Kenya.

High-yielding, widely adapted	High to medium altitude, low to intermediate mean temperature	High-yielding, medium altitude, intermediate temperature	Medium to low altitude, high mean temperature
ICPL 84031	Kat 60/8	ICPL 83016	ICPL 86005
ICPL 86020	KZ 69/2	ICPL 85045	ICPL 87101
ICPL 86023	KZ63	ICPL 86023	ICPL 89016
ICPL 87091	KO109	ICPL 90009	ICPL 89031
ICPL 87109	Upas 120	ICPL 90043	ICPL 90029
ICPL 87114	ICPL 83024	ICPL 90053	ICPL 90031
ICPL 88018	ICPL 86029	ICPL 91004	
ICPL 89008	ICPL 87115		
ICPL 89015	ICPL 88034		
ICPL 89017	ICPL 89001		
ICPL 89031	ICPL 89004		
ICPL 90013	ICPL 89014		
ICPL 90036	ICPL 89015		
ICPL 90043	ICPL 89018		
ICPL 90044	ICPL 89019		
ICPL 90050	ICPL 89030		
ICPL 91036	ICPL 89037		
	ICPL 90032		
	ICPL 90033		
	ICPL 90034		
	ICPL 90045		

Medium- and long-duration pigeonpea

Medium- and long-duration pigeonpea cultivars of diverse origin were grown along the Kenya transect at Mombasa under natural daylength (12 h ± 15 min) and under natural and extended (=14 h ± 30 min) daylengths at Kiboko, Katumani, and Kabete. Mean temperatures vary from high at Mombasa to low at Kabete, with increase in altitude (Table 1).

Height and biomass. Plant height and biomass production were highest at Mombasa, where mean temperature is high. There was a gradual reduction in height and biomass with a reduction in temperature, such that the shortest plants and lowest biomass were recorded in Kabete, which had the lowest mean temperature.

Medium- and long-duration cultivars under natural daylength

Phenology. Of the 48 lines tested under natural daylength, 29 flowered at Mombasa, 40 at Kiboko, 47 at Katumani, and 48 at Kabete (Table 6). All the test entries

Table 5. Days to flower and percentage change in days to flower due to reduction in growing temperature for extra short and short-duration genotypes, Kenya, 1992/93.

Genotype	Days to flower at Kiboko	Percentage change in days to flower from Kiboko at	
		Katumani	Kiboko
KO 91	110	21	2
KO 71/3	103	-8	12
KZ 69/2	94	47	14
Kat 50/3	85	12	15
KO109	88	16	15
ICPL 83016	79	-4	16
KZ63	91	17	18
Kat 60/8	84	17	22
ICPL 87108	62	16	38
ICPL 87109	63	20	40
ICPL 86005	62	23	40
ICPL 89030	62	16	40
ICPL 91009	59	17	41
ICPL 87091	65	16	41
ICPL 86023	63	16	44
ICPL 87 W	*60*	20	45
ICPL 90037	59	22	46
ICPL 90013	62	17	46

Table 6. Influence of temperature and photoperiod on height, phenology, 100-seed mass, and grain yield in medium- and long-duration pigeonpea, Kenya, 1992/93.

Attribute	Mombasa[3]		Kiboko[4]		Katumani[5]		Kabete[6]	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Plant height (cm)[1]	99-310	220	67-285	210			44-173	114
Plant height (cm)[2]			173-388	285			40-169	116
Days to flower[1]	78-155	126[a]	67-269	148[b]	88-235	124[d]	97-138	118[f]
Days to flower[2]			94-279	190[c]	83-282	176[e]	102-192	132[g]
Days to maturity[1]	134-184	162	124-268	182	132-268	178	158-209	180
Days to maturity[2]			147-325	251	155-303	219	172-230	201
100-seed mass (g)[1]	9.8-17.1	13.1	8.3-18.1	12.0			9.6-20.9	14.5
100-seed mass (g)[2]			7.6-19.0	12.9			9.2-21.3	13.9
Grain yield[1] ($t\ ha^{-1}$)	0.73-2.67	1.75	0.66-3.63	1.75			0.53-2.93	1.86
Grain yield[2] ($t\ ha^{-1}$)			0.94-4.92	2.72			0.42-3.11	1.33

Daylength: 1 = normal, 2 = extended.
Number of lines that flowered: a = 29, b = 40, c = 37, d = 47, e = 48, f = 48, g = 48
Temperature at various locations: 3 = high mean, 4 = high mean with moderate night temperatures, 5 = intermediate, 6 = cool.

flowered and produced grain at Kabete (low mean temperatures), and most flowered and produced grain at Katumani (intermediate maximum, low minimum temperatures). The cultivars that originated from high altitude or latitude and were long-duration types, failed to flower at Mombasa (high temperatures); at Kiboko they were either late in phenology or failed to flower. The inhibition in flowering was greatest at Mombasa. When the whole transect is considered, results show that most of the lines that flowered at Mombasa flowered earliest at Kiboko and progressively later at Katumani, Kabete, and Mombasa (Table 6). The cultivars that failed to flower at Mombasa experienced a progressive acceleration in phenology with decrease in temperature (increase in elevation), such that flowering and maturity were earliest at Kabete.

We used the component of the photothermal model $1/f = a + bT$ to determine response to flowering.

Results show that crop responses to variation in temperature were basically two: medium-duration cultivars that flowered at Mombasa (high mean temperature) and long-duration cultivars that did not flower at Mombasa. The optimum temperature at which flowering is most rapid in medium-duration cultivars was 22-24°C, which is similar to that for short-duration cultivars. Temperatures below or above the optimal led to delayed flowering. At high elevation (sub-optimal temperature) ICPs 9191, 10816, 11984, 12113, 12130, and 13510, Tanz 9, and Tanz 23 were stable, as shown by minimum delay in flowering. At supra-optimal temperatures Gujarat Local and ICPs 9191, 11984, and 13582 were stable, as shown by minimum delay in flowering. The results thus show that among the medium-duration cultivars tested, ICP 9191 is stable across a wide range of environments. Across the whole transect, the phenology of long-duration cultivars was accelerated by decrease in temperature, suggesting that long-duration pigeonpeas flower earliest at lower temperatures than the ones tested. We are presently testing at even lower temperatures to determine the point at which flowering is most rapid. In addition, the study has indicated differences among long-duration cultivars: those originating from high elevations (where temperatures are low) or high latitudes (where days are long during vegetative growth and temperatures are low during reproductive growth) experience greater delay in phenology than do cultivars from intermediate altitudes/latitudes, when grown in areas warmer than their areas of adaptation (Table 7).

Grain yield. Results show that medium-duration cultivars were generally better adapted and gave high yields in areas with high to intermediate temperature, i.e., areas of low to intermediate elevation (<1500 m). We have constituted a nursery consisting of the most promising medium-duration lines, which is now being tested in Kenya. The nursery could also be sent, on request, to Uganda and Tanzania for testing.

Long-duration cultivars are better suited to areas with intermediate to low temperatures. We have selected seven cultivars specifically for high elevation: Kat 840, ICP 12783, Farmer 20, Farmer 28, Farmer 31, Farmer 33, and Kenya 5. In the 1994/95 season these will be tested in the Babati area in northern Tanzania. Subse-

Table 7. **Effect of temperature under natural daylength (12 h ± 20 min) on number of days to flower in selected pigeonpea cultivars of different origin at four locations in Kenya, 1992/93.**

Genotype	Origin: Location	Origin: Altitude (m)	Days to flower at: Mombasa	Kiboko	Katumani	Kabete
ICP 7035	India: Madhya Pradesh	<500	122	86	95	110
ICP 8800	India: Haryana	<500	103	78	103	108
Kat 777	Kenya: Katumani	=1560	*	211	119	123
ICP 9191	Kenya: Kisumu	=1000	117	93	113	115
T7**	India: Uttar Pradesh	<600	*	163	152	132
Kenya 10	Kenya: Machakos	1070	*	234	143	135
ICP 13470	Malawi		155	134	135	127
ICP 6927	Trinidad	<100	119	80	102	120
ICP 13510	Malawi		*	192	122	122
Gujarat Local	India: Gujarat	<300	117	91	110	118
ICP 13252	Kenya: Malindi	<100	112	89	120	117
ICP 9150	Kenya: Makueni	-1100	*	178	131	128
ICP 12783	Tanzania: Mbeya	>1400	*	219	128	123
ICP 13562	Ethiopia: Diban		*	127	138	125
Tanz 23	Tanzania: Nachingwa	470	*	140	110	115
ICP 11984	Philippines: Pingad	<300	149	108	109	114
ICP 10816	India: Assam	<300	93	75	97	98
Kat 81/3/3	Kenya: Katumani	1560	137	133	111	121
ICP 13089	Kenya: Meru	=600	149	143	127	119
Kenya 6	Kenya: Sultan Hamud	1200	*	255	149	130
ICP 12085	Tanzania: Kondoa	-1100	*	198	146	132
Babati 1	Tanzania: Babati	1200	*	154	151	128
Tanz 9	Tanzania: Masasi	410	127	96	112	117
ICP 9161	Kenya: Kilifi	<100	139	79	104	117
ICP 12134	Tanzania: Kilosa	<700	*	206	150	127

* did not flower
** from high latitude

quently, we will also constitute and distribute nurseries of long-duration cultivars for intermediate elevations and high latitudes.

Medium- and long-duration cultivars under extended photoperiod

Extending photoperiod delayed flowering and maturity. The effect was greatest at Kiboko, where mean maximum temperatures are high. Cultivars that showed less inhibition of flowering under extended photoperiod were those that originated from high elevations, e.g., Kenya 10, Babati 10, and ICP 12782.

Conclusions

The study indicated that medium- and long-duration pigeonpeas have specific adaptation. Cultivars from low elevation are mostly medium duration, and have high optimum temperature for rapid flowering, similar to the short-duration cultivars. Long-duration cultivars have low optimum temperature (<18°C) for rapid flowering, and are therefore able to flower and produce grain at intermediate to high elevations or latitudes, where temperatures are intermediate to low. The study has further indicated that there are differences among the long-duration cultivars, with lines originating from high-elevation (low-temperature) areas experiencing delayed flowering when grown at intermediate elevations.

Although we have used the prediction of phenology to target cultivars to specific areas, high grain yield and acceptable grain size are still major considerations during selection.

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Pigeonpea Improvement in Malawi

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Introduction

Pigeonpea is a very important food legume crop in most parts of Malawi. It is grown mostly in the southern and central regions (Ngabu, Blantyre, Machinga, and Salima Agricultural Development Divisions, or ADDs) and in some parts of Karonga ADD in the north. There is considerable potential for expansion in other medium-altitude areas with higher rainfall but lower temperatures, e.g., Lilongwe, Mchinji, Kasungu, Mzimba, Rumphi, and Chitipa plains. Long-duration photoperiod-sensitive landraces are grown, usually intercropped with staple food crops (maize, sorghum, and cassava).

These are sown with the onset of the rains, but because the genotypes are late-maturing, end-of-season drought coupled with declining temperatures and shortening day lengths, reduce yields. Attempts to extend production to areas with adequate rainfall have failed largely because, although the cultivars grew well, they failed to ripen at the low temperatures prevalent at the end of the season.

The extension of pigeonpea to these new areas is likely to require different ideotypes that have a sufficiently short growth period and can use as much as possible of the favorable season for yield-forming activities.

Research programs

This paper summarizes the pigeonpea work conducted by the Malawi national program during the 1993/94 season. The major activity was evaluation of material; trials were conducted at various locations to evaluate genotypes from each maturity duration group.

Advanced Pigeonpea Variety Evaluation Trial (APVET - 1992/93)

Objective. To evaluate short- and medium-duration genotypes for adaptability, grain yield, and seed characteristics in different agroecological environments in Malawi.

Materials and methods. During 1992/93 six medium-duration, photoperiod-sensitive genotypes (QPs 14,15, 37, and 38, HY 3C, and Royes) and five short-duration,

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photoperiod-insensitive genotypes (ICPLs 151, 86005, 86012, 87105, and 87 C) were evaluated on-station at Baka (9° S), Chitedze (14° S), Chitala (13.5° S), Makoka (15.5° S), and Ngabu (16.5° S). A randomized complete block design was used with four replications. Plot size was four ridges, 6 m long, spaced 90 cm apart. The net plot consisted of the two middle ridges.

Sowing dates were 24 Nov at Chitedze, 20 Dec at Makoka, 23 Dec 1992 at Baka, 3 Jan at Chitala, and 15 Jan 1993 at Ngabu. At Chitedze and Chitala the crop was adversely affected by drought; the Chitala trial was written off. Termite attack was common at all sites, and this reduced stand count. The major insect pests included flower and pod borers *(Maruca testulalis, Mylabris pustulata)* and pod-sucking bugs *(Nezara viridula, Clavigralla* spp). These were controlled by spraying carbaryl 85.

Results. Results are shown in Table 1. In general, plants flowered and matured earliest, and were the shortest, at Ngabu. Flowering was most delayed at Chitedze, and maturity was most delayed at Makoka and Baka. Across-location means for the different genotypes ranged from 73 (ICPL 87105) to 146 (Royes) days to 50% flowering, and from 111 (ICPL 86005) to 197 (QP 15) days to maturity. At all sites except Baka, there were significant differences between varieties in the number of pods plant*^{1}, which was highest at Baka and lowest at Makoka. Across sites, ICPL 86005 produced the largest number of pods. Seed size was largest at Makoka and smallest at Chitedze. Across sites, QP 38 had the largest seed (15 g 100 seed^{1}). The best yielders across sites were ICPL 9145 (0.98 t ha^{-1}) and Royes (0.94 t ha^{1}).

Collaborative activities with ICRISAT

The Malawi national program collaborates with the ICRISAT Pigeonpea Improvement Project in several areas. In addition to the ongoing activities such as germplasm exchange, training, etc., two areas of collaboration are also important, and are discussed below:

- On-farm Multi-environment Advanced Varietal Trial
- Other multilocational trials conducted in Malawi.

On-farm Multi-environment Advanced Pigeonpea Varietal Trial

Materials and methods. In 1992/93 and 1993/94 two promising medium-duration (Royes, QP 38) and three short-duration (ICPLs 151, 86005, 87105) lines were evaluated on farmers' fields in seven of the eight ADDs in Malawi. The test sites were characterized by varied ecologies, and included both traditional and non-traditional pigeonpea areas. The trials were sown by each farmer in a randomized complete block design with four replications. Sowing was delayed at all sites because the rains came late, and this led to reduced yields.

Table 1. Yield and yield components of advanced pigeonpea lines at four locations in Malawi, 1992/93.

	100-seed mass (g)					Grain yield (t ha^{-1})				
Genotype	Chitedze	Makoka	Baka	Ngabu	Mean	Chitedze	Makoka	Baka	Ngabu	Mean
QP 14	10	15	15	12	12	0.30	0.99	1.12	1.32	0.93
QP 15	10	15	15	11	12	0.44	0.75	0.71	1.03	0.73
QP 37	10	16	15	12	12	0.30	0.82	0.62	0.96	0.68
QP 38	13	17	18	14	15	0.47	0.71	0.79	0.90	0.72
Royes	10	15	15	12	13	0.61	0.98	1.56	0.61	0.94
HY 3C	11	16	15	12	13	0.36	1.06	0.99	0.83	0.81
ICPL 86012	11	13	10	10	10	0.29	0.24	1.32	1.25	0.77
ICPL 87105	13	13	11	12	12	0.54	0.67	0.70	1.30	0.80
ICPL 87 C	10	12	11	9	10	0.39	0.56	0.80	1.19	0.74
ICPL 151	10	12	10	8	9	0.23	0.35	1.00	0.73	0.57
ICPL 86005	9	12	11	9	9	0.62	0.69	0.78	0.84	0.73
ICP 9145 (control)	9	16	13	13	12	0.28	1.36	0.59	1.67	0.98
Mean	10	14	13	11		0.40	0.76	0.91	1.05	
SE ±	1.2	0.3	0.9	9.7		0.098	0.146	0.174	0.230	
CV (%)	24.6	4	14	19		54	38	38	55	
Significance	ns	**	**	*		ns	**	**	*	

*, **, *** significant at 1%, 5%, and 10% respectively, ns = not significant

Results and discussion. At the time of writing, results were available from only three ADDs (Table 2). These results are only preliminary. The extra short duration lines (ICPL 87105, ICP 151 C, ICP 86012) at Lughali and Lufita are prone to damage by insect pests, particularly flower beetles. They may not provide reasonable yields unless insecticides are used.

Table 2. On-farm pigeonpea grain yields (t ha^1) at five locations in Malawi, 1993/94.

Genotype	Lughali	Lufita	Chiwebu	Chilipa	Chipoka
QP38	NH[1]	NH	_	0.26	0.23
Royes	NH	NH	1.32	0.29	0.19
Local	NH	NH	1.06	0.19	0.22
ICPL 87105	0.61	1.20	0.57	0.44	0.21
ICPL 86012	0.76	0.84	0.54	0.46	0.19
ICPL 151 C	0.79	0.72	0.71	0.44	0.22

1. Not harvested at the time of writing.

At Chilipa and Chipoka, no pest assessment was made since only shelled samples were available. However, a visual estimate indicated that short-duration varieties were considerably more susceptible to *Helicoverpa* than were the medium- and long-duration varieties. There is a need to continue these on-farm trials, especially as the short-duration varieties have the ability to escape terminal drought.

Other research activities

In the 1993/94 season, four nurseries were grown at Chitedze:

- F_1 progenies
- F_2 populations
- Individual plant selection nursery
- Observation nursery.

Several short- and long-duration replicated trials were also evaluated at three other locations in Malawi.

- Regional Short-duration Pigeonpea Trial
- Extra Short Duration Pigeonpea Trial (Determinate)
- Extra Short Duration Pigeonpea Trial (Indeterminate)
- Short-duration Pigeonpea Trial (Determinate)
- Short-duration Pigeonpea Trial (Indeterminate)
- Vegetable Pigeonpea Trial
- Regional Long-duration Trial
- Long-duration Pigeonpea International Trial
- Medium-duration Pigeonpea International Trial.

Table 3. Results from five pigeonpea trials conducted at various locations in Malawi, 1993/94.

Trial[1]	Seed yield ($t\ ha^{-1}$) range[2]	100-seed mass (g) range[2]	Highest yielders ($t\ ha^{-1}$)	Largest seed sizes ($g\ 100\ seed^{-1}$)
ESD, determinate[3]	0.95-2.02	7.4-11.2	ICPL 90008 ICPL 91004 (1.98)	ICPL 90011 ICPLs 91004, 92028 (11.0)
ESD, indeterminate[3]	0.96-2.15	9.2-11.7	ICPL 92047 ICPL 92048 (2.07)	ICPL 91053 ICPL 91052 (11.5)
SD, determinate[3]	0.88-2.49	9.9-14.9	ICPL 91018 ICPL 91021 (2.33)	ICPL 90028 ICPL 91018 (13.5)
SD, indeterminate[3]	1.47-2.23	7.5-11.6	ICPL 92044 ICPL 92045 (2.22)	ICPL 91036 ICPL 92041 (10.9)
Regional SD[4]	0.56-1.03	10.3-13.5	ICPL 90028 ICPL 90029 (0.92)	ICPL 90029 ICPL 87105 (13.3)

1. ESD, SD = extra short, short-duration.
2. Range of means (for the different genotypes, averaged across locations). All figures averaged across locations.
3. Conducted at 3 locations (Baka, Chitedze, Ngabu).
4. Conducted at 4 locations (Makoka, Baka, Chitedze, Ngabu)

Trials/nurseries. Several nurseries and trials have been evaluated for yield and other agronomic characteristics at Baka, Chitedze, Makoka, and Ngabu. Data on phenology, yield, and yield components were recorded. All the short-duration nurseries have been harvested and the data analysed; most of the long-duration trials have yet to be harvested and/or analyzed. Therefore, the results are presented only for short- and extra short duration varieties. Five trials were conducted:

- Regional Short-duration Trial
- Extra Short Duration (Determinate) International Trial
- Extra Short Duration (Indeterminate) International Trial
- Short-duration (Determinate) International Trial
- Short-duration (Indeterminate) International Trial.

Results of the five trials are summarized in Table 3. In the Extra Short Duration (Determinate) International Pigeonpea Trial, Baka (2.78 $t\ ha^{-1}$) and Ngabu (1.3 t $ha-^{1}$) had the highest location means. ICPL 90008 was the highest yielder with an overall mean of 2.02 $t\ ha^{-1}$. In general, most of the entries were small-seeded. In the Short-duration (Determinate) Trial, Ngabu had the highest location mean (2.48 t $ha-^{1}$), followed by Baka (2.41 t $ha-^{1}$). Several lines yielded over 3 $t\ ha^{-1}$ at Baka and Ngabu. The highest overall varietal mean was recorded for ICPL 91018, which also had acceptable seed size. Entries in the indeterminate short- and extra short duration trials gave very high yields at both locations (Baka and Ngabu). Yields in the regional yield trial were low at all locations, mainly due to low plant population. Baka and Makoka had mean yields over 1 $t\ ha^{-1}$.

Screening Pigeonpea Lines for Resistance to Root-knot Nematodes

A T Daudi and D W Makina[1]

Introduction

Pigeonpea (*Cajanus cajan)* is an important pulse crop in Malawi, grown for both local consumption and export. Most of the crop is produced in southern Malawi, with scattered production areas in the central and northern regions. It is usually mix-cropped with maize. Pigeonpea could also be promoted as a potential rotation crop on commercial tobacco estates. Commercial tobacco farmers in Malawi rotate tobacco (usually with maize, and sometimes with fallow for 3-4 years), essentially to reduce populations of root-knot nematodes, *Meloidogyne* spp.

The pigeonpea landraces in Malawi are all susceptible to root-knot nematodes, and would increase, rather than reduce nematode populations if they were used in rotations with tobacco. Nematode-resistant pigeonpea varieties would thus have a good potential for adoption, particularly since pigeonpea (along with *Phaseolus* beans) forms a major part of the food that is distributed free to tobacco farm workers. Growing pigeonpea on the estate, rather than purchasing it from outside, would indirectly help reduce tobacco production costs.

Some pigeonpea lines resistant to *Meloidogyne javanica* were identified at ICRISAT Asia Center, India. These were brought to Malawi in 1992/93 for further screening against root-knot nematodes under Malawian conditions. The varieties or lines thus identified will be released for cultivation in rotation with tobacco and other crops.

Materials and methods

The experiment was conducted at the Bvumbwe Research Station farm (1183 m asl), in a field naturally infested with mixed populations of M. *javanica* and *M. incognita.* Ten pigeonpea lines were sown in single rows on 13 Dec 1993. These were ICPs 24, 72, 151, 8357, 11289, 11299 and 86030, and ICPLs 8, 157, and 87113. The popular variety ICP 9145 was used as a control.

Five plants of each line were uprooted 60 days after sowing to assess nematode invasion in the roots. Roots were stained as described by Southey (1970) and modified by the Rothamstead Experimental Station (Janet Macon, personal communication 1989). The roots were boiled for 3-5 min in a solution consisting of equal parts of glycerol, lactic acid, and distilled water, plus 0.05% acid fuchsin. They were then washed in water and placed in small bottles containing a clearing solution

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Table 1. Characteristics of 11 pigeonpea lines, Bvumbwe Research Station, Malawi, 1993/94.

Genotype	Maturity duration	100-seed mass (g)	Plant height (cm)	Days to 50% flowering
ICP 9145	Long	13.9	268	108
ICP 86030	Short	12.3	131	77
ICPL 87113	Short	11.2	131	103
ICP 8357	Medium	10.6	195	162
ICP 11299	Long	10.5	260	155
ICPL 8	Short	9.8	103	69
ICP 11289	Long	9.0	264	•
ICP 24	Long	8.6	138	91
ICPL 157	Short	8.1	74	62
ICP 151	Short	8.1	56	76
ICP 72	Medium	7.7	182	108

* No germination

(50:50 glycerol: distilled water) for 2-3 days before observation. The roots were then removed from the clearing solution, chopped into small pieces of 1-2 cm, and macerated in an ordinary kitchen blender. Water was then added to make up the mixture to 100 mL. A 10 mL pipette was used to pipette 5 mL aliquots, and the nematodes on the roots were counted on a counting dish using a stereo microscope.

At harvest all remaining plants were uprooted to assess the extent of nematode galling. Galling was measured on a 0-5 scale, where 0 = no nematode infestation, 1 = up to 20% damage, 2 = up to 40% damage, 3 = up to 60%; 4 = up to 80%, and 5 = up to 100% damage. No yield data were recorded.

Results and discussion

Total rainfall during the growing season (Nov 1993 to Jun 1994) was 595 mm, of which 510 mm fell between Jan and Mar 1994.

The 11 pigeonpea lines tested had different growth habits (Table 1). Farmers in southern Malawi prefer long-duration lines because they use the stems for firewood. In central Malawi, particularly in districts (e.g., Salima and Dedza) along the lake shore, short, short-duration lines are preferred because they mature at the same time as maize. This allows farmers to graze their livestock in the fields without any fear of unharvested pigeonpea being destroyed. Some of the lines have seed sizes similar to that of the popular ICP 9145, and are therefore more likely to be accepted by farmers.

The first observations on nematode invasion were done 60 days after sowing (Table 2). The results were consistent with those obtained in 1992/93. Differences were seen only in varieties that were nematode-resistant.

Table 2. Nematode invasion and galling index in roots of 11 pigeonpea lines, Bvumbwe Research Station, Malawi, 1993/94.

	Nematodes mL^{-1} water at 60 DAS[1]		Root-knot nematode index at harvest	
Genotype	1992/93	1993/94	1992/93	1993/94
ICPL8	11	5	0	0
ICPL1572		0		0
ICPL87113	11	0	0	0
ICP24	10	0	0	0
ICP72	1	13	0.9	2.9
ICP151	6	1	0	0
ICP 8357	23	1	0.9	0.6
ICP9145	0	0	0	0
ICP 11289	9	0	0	2.0
ICP 11299	16	0	0	0.2
ICP 86030	24	0	0.5	0

1. Days after sowing
2. Tested in 1993/94 for the first time in Malawi

Resistance in ICP 9145 has been consistent during the two seasons. However, our results conflict with those obtained by Hillocks and Khonga (1993), who found ICP 9145 to be susceptible. Three other lines showed some promise: ICP 24, ICP 157, ICPL 8, and ICPL 87113. ICPL 8 and ICP 151 (another line with possible resistance) suffered an initial invasion, but the nematodes did not grow to full maturity. Probably the nematode feeding sites in the roots were not developed, a form of resistance in these two lines. ICP 157 was tested for the first time in 1994 and looks resistant to nematodes; it will be tested further in 1994/95. ICPL 87113 and ICP 24 were invaded at 60 days after sowing, but not at harvest, in 1993. Neither line was invaded in 1994. These are interesting results, but closer observation is needed to authenticate the resistance of these two lines.

In 1992/93, ICP 86030 suffered nematode invasion at 60 days after sowing and at harvest. However, there was no invasion in 1994. This could be due either to resistance or to patchy distribution of nematodes in the field, permitting the line to escape invasion. This will be verified next season.

ICP 72 and ICP 8357 were susceptible to root-knot nematodes in both seasons. Nematode invasion came towards the end of the growing season in ICP 11289 and ICP 11299. In 1993 these were invaded initially but not at harvest. There is need for further observations before any conclusive results can be tabled.

The preliminary observations thus indicate that three short-duration lines (ICPL 8, ICP 151, and ICP 87113) and one long-duration line (ICP 24) are resistant to root-knot nematodes. These lines have consistently reduced nematode multiplication, and the 1994/95 results may provide conclusive evidence.

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Pathogenic Variability in *Fusarium udum*, the Incitant of Wilt in Pigeonpea

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Introduction

Pigeonpea *(Cajanus cajan)* is one of the major grain legumes in Malawi. Green or dry seed is used as a vegetable, and eaten with such staples as maize, cassava, sorghum, and rice. The green leaves are used as livestock feed, and the stems serve as fuel wood. Pigeonpea is currently gaining a place in agroforestry as a nitrogen fixer and also to control soil erosion, particularly on steep slopes. Until 1987, annual production in Malawi fluctuated tremendously due to, among other factors, lack of cultivars resistant to insect pests and diseases, especially fusarium wilt *{Fusarium udum).*

Fusarium wilt is a major cause for the declining trend in pigeonpea production in the country. In 1987 a high-yielding, fusarium wilt resistant cultivar, ICP 9145, was released. ICP 9145 is also drought-resistant, late-maturing, and large-seeded (15 g 100 seed^{-1}). Since the release of this cultivar its adoption has increased from 19 904 ha to 37 309 ha by the 1990/91 growing season, and yields from 432 to 627 kg ha-^{1}. The pigeonpea area in Malawi is still increasing (Babu et al. 1992).

The release of ICP 9145 represents substantial progress in controlling fusarium wilt. However, evidence from India has shown that races of F. *udum* do exist (Gupta et al. 1988, Reddy and Raju 1993). This implies that the resistance in ICP 9145 can at some point break down, leaving smallholder farmers with no other cultivar to grow. Hence, the main objectives of the study were to:

- Investigate the occurrence, distribution, and prevalence of pathogenic races of F. *udum* in all major pigeonpea-growing areas in Malawi
- Conduct field and greenhouse screening of the pathogenic races of F. *udum* against a range of local landraces, wilt-resistant germplasm, and breeding lines including ICP 9145, and other African germplasm, in the hope of identifying lines with broad-based, stable resistance to fusarium wilt.

Field survey

A field survey covering 13 districts in northern and southern Malawi (the main production areas in the country) was conducted from Aug to Nov 1993. A systematic

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sampling design survey was used to assess farmers' fields at intervals of 5-15 km along accessible routes within a district. A total of 312 samples, each consisting of both soil and wilted plants, were collected. The samples were collected at random, 2-6 samples per field, depending on its size. For each of the fields surveyed, additional information was gathered on crop history including cropping pattern, area under pigeonpea in the same field and/or within the ecological area, state of crop growth, and incidence of other diseases and insect pests. The samples were then brought to the laboratory for isolation of *F. udum,* soil classification, and determination of pH.

Laboratory studies—isolation and purification

Soil. One gram of soil was added to 9 mL of sterile distilled water in a test tube. The contents were thoroughly mixed and subsequent serial dilutions up to 10 dilutions were made. One milliliter of soil suspension from each of test tubes 2 to 10 was separately placed and spread with the aid of a sterile L-shaped glass rod over Nash-Snyder medium (Tuite 1969). Each dilution was replicated five times and the plants were incubated at 25 °C for 24 h. Fungal colonies resembling *Fusarium* were subcultured and reincubated at 25° C for 4 days. This procedure was followed for each of the 312 samples.

Wilted plants. Pieces (0.5-1.0 cm^2) from wilted plant materials were cut using a sterilized scalpel and surface-sterilized in 1% sodium hypochlorite for 1-2 min. The tissues were washed in two series of sterile distilled water and blotted with sterile paper towels. Five pieces were placed on each plate and replicated twice. The plates were incubated at 25 °C for 4 days. This procedure was followed for each of the 44 samples.

Purification. After 4 days a piece of the fungal colony from both soil and wilted-plant isolates was purified using the single-spore culture technique described by Tousson and Nelson (1976) for further studies on growth rate, growth pattern, pigmentation, morphology of the conidia, sporulation, and pathogenicity.

Laboratory studies—cultural characteristics

Data on growth rate, growth pattern, pigmentation, morphology of the conidia, and sporulation were collected on the tenth day after incubation of isolates at 25 °C.

Laboratory studies—pathogenicity

Single-spore isolates were multiplied in 250 mL conical flasks containing potato dextrose broth and placed on a rotary shaker for 10 days at room temperature (25-30°C). Seeds of a highly susceptible pigeonpea line (ICP 2376) were surface-sterilized for 1 min and planted in polythene bags filled with sterilized sand. The bags were kept in the greenhouse at 25-30°C and watered with sterile distilled water. After one week of germination each seedling was inoculated, using an inoculation concentration of 1 x 10^6 spores mL^{-1}, using the root-dip and transplanting method (Gupta et al. 1988) and subsequently transplanted into 15 cm diameter plastic pots containing a sterilized mixture of red soils and river sand (3:1 v/v). Five seedlings were inoculated with each of the 104 isolates, with three replications. The pots were placed in the greenhouse at 25-30°C in a completely randomized block design and irrigated with sterilized distilled water.

Survey results

Fusarium wilt was the most widely distributed disease in both regions, present in all districts except Chitipa. Mean wilt incidence was found to be 5.4%. These findings substantiate the reports from earlier surveys by Subrahmanyam et al. (1992) and Reddy et al. (1992).

Other diseases observed during the survey were powdery mildew (*Leveillula taurica)* and cercospora leaf spot *(Mycovellosiella cajani).* Powdery mildew was observed in Mwanza district, while cercospora leaf spot was prevalent in Mwanza, Thyolo, and Blantyre districts. The pests observed included scales (*Ceroplastodes* spp) and red mites *(Tetranychus* spp) in some fields in Karonga, and termites *[Odontotermes* spp) in some fields in Blantyre.

Soko (1992) reported that pigeonpea was mainly mix-cropped with staple food crops. This survey is in agreement with his findings. Out of 132 farmers' fields surveyed 130 (99%) had pigeonpea intercropped with other crops. Common staples observed in intercropped fields included maize, cassava, sorghum, and bananas. However, the presence of other leguminous crops (groundnuts, beans, and cowpeas) was not uncommon.

Results of laboratory studies

Growth rates of the colonies of each isolate were recorded every day for 10 days. The study has shown that 103 (28.4%) isolates are fast growers, while 216 (59.5%) have growth rates close to the average. Only 44 (12%) isolates are slow growers. Generally, most isolates (95%) from the northern districts are slow growers (growth rates below the mean), while 75% those from the southern districts are fast growers (growth rates above average).

On Nash-Snyder medium, 332 isolates (91.7%) developed smooth colonies, while 30 (8.3%) developed irregular colonies. Furthermore, a wide range of mycelial characteristics was observed, including fluffy growth (284 isolates, 78.5%), dense aerial mycelia (29, 8%), radial strands (23, 6.4%), porous mycelia (7, 1.9%), and dense mycelia without concentric rings (3, 0.8%). The majority of the isolates (197) did not produce pigments, although a few were light yellow or pale pink.

Although the isolates were fast growers they were poor sporulators (<14.2 x 10^6 spores mL^{-1}); 248 isolates were poor sporulators whereas 9 isolates were classified as abundant sporulators (>27.4 x 10^6 spores mL^{-1}).

The isolates produced both microconidia and macroconidia. Measurements using a microscope indicated an average size of 10-25 x 3-7 u for microconidia and 30-50 x 3-7 u for macroconidia. These measurements are within the range reported by Booth (1971), i.e., 30-40 x 3-3.5 u for both microconidia and macroconidia. This implies that the isolates are indeed *F. udum.*

When 60 isolates from the northern region were inoculated onto the highly susceptible pigeonpea line ICP 2376, all but seven isolates were pathogenic.

Conclusions

It is apparent from the survey that there is a reduction in wilt from an average of 36% (Kannaiyan et al. 1984) to 5.4%. This reduction can probably be attributed to the use of ICP 9145. While laboratory studies have succeeded in isolating and purifying isolates, further work is needed to test the isolates on ICP 9145, and to identify pathogenic variability among the isolates.

Future plans

- Pathogenicity tests to continue
- Further characterization of isolates, and surveys in pigeonpea-growing areas
- Field trials using ICP 9145 and other germplasm in farmers' fields where isolates were obtained. These will be conducted during the 1994/95 growing season.

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Breeding Pigeonpeas for High Yield, Stability, and Adaptation

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Introduction

Pigeonpea is grown on approximately 2.6 million ha in 54 countries; world production is 2.55 million t. Among the grain legumes, pigeonpea ranks sixth in area and production (Sharma and Green 1975). Besides India, the crop is important in Africa, especially in Kenya, Malawi, Tanzania, and Uganda. Average yields are rather low (0.7 t ha^{-1}}. Some of the reasons for this low productivity are:

- Lack of high-yielding cultivars
- Loss of grain due to pests and diseases
- Poor crop management
- Inadequate research.

Causes of low productivity

Lack of high-yielding cultivars. In most countries farmers are still using landraces. It has been demonstrated that pigeonpea yield could be increased by 100% or more by using wilt-resistant cultivars. Forexample, after the release of ICP 9145 in Malawi, the area under pigeonpea increased from 19 904 ha in 1986 to 37 309 ha in 1991 (Babu et al. 1992).

Losses due to insects and diseases. Insects and diseases continue to devastate the crop every year. Among the insects, pod borers *(Helicoverpa armigera* and *Clavigralla* spp) and sucking bugs (*Nezara viridula)* are dangerous and common in Africa (Reed and Lateef 1990). Among the diseases, wilt caused by *Fusarium udum* and leaf spot disease *(Cercospora cajani)* are important.

Poor crop management. Short-duration pigeonpea can be produced on fallow lands in cereal-fallow, cotton-fallow, and/or tobacco-fallow production systems. This will increase pigeonpea production, and also provide additional income to farmers.

Inadequate research. Unlike soybean or beans, research on pigeonpea is limited to Asia and Africa. The bulk of the research is conducted in Asia, particularly on the Indian subcontinent. Research programs for this crop in Africa are recent, and are limited to a few countries. Research efforts need to be considerably intensified to properly exploit the potential of the crop.

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Recently, considerable emphasis has been given to research on pigeonpea improvement in Africa. Two years ago, very few countries in eastern and southern Africa conducted collaborative research on pigeonpea. Today, 11 out of 17 countries in the region are involved in such research. Since the establishment of the Pigeonpea Improvement Project, more than 110 nurseries consisting of over 4000 pigeonpea samples have been distributed in the region (Table 1). In addition, the number of requests for seed and for collaborative research programs, from both government and private organizations, has increased.

Breeding objectives

The overall objective of the Pigeonpea Project is to increase pigeonpea production in eastern and southern Africa. This will be sought to be achieved through the supply of elite germplasm and breeding lines to the national and regional programs. The common objective is to develop superior pigeonpea varieties that are high yielding and resistant to fusarium wilt and/or other diseases. The specific objectives are related to crop improvement in different areas.

- Traditional pigeonpea areas—the major emphasis is on the improvement of landraces. Many local cultivars are susceptible to fusarium wilt disease. Therefore, one specific objective is to develop wilt-resistant genotypes similar to the landraces in seed taste, size, and color.
- Non-traditional pigeonpea areas—the objective is to develop widely adapted cultivars suitable for the existing cropping system. The emphasis will be on short-duration genotypes adaptable to drought-prone areas and useful for growing on fallow lands, particularly in cereal-fallow, tobacco-fallow, and cotton-fallow.

Table 1. Number of pigeonpea seed samples supplied to NARS programs in southern and eastern Africa, 1992-94.

	Germplasm lines		Breeding materials		Advanced lines	
Country	1992/93	1993/94	1992/93	1993/94	1992/93	1993/94
Kenya	-	-	-	-	-	44
Lesotho	-	-	-	-	-	24
Malawi	1355	575	688	320	346	62
Mozambique	130	20	-	-	-	24
Namibia	-	-	-	-	92	44
Swaziland	-	-	-	-	-	44
Tanzania	-	-	-	-	92	60
Zambia	-	-	.	-	92	44
Zimbabwe	-	-	-	-	-	24
Total	1485	595	688	320	622	370
Grand total						4080

Breeding methods

Pigeonpea is a self-pollinated species with a high outcrossing rate. We used modified bulk and back-cross breeding methods to develop cultivars, and are making 2- and 3-way crosses to incorporate desirable characteristics into local landraces and/or elite breeding or germplasm lines. The major characteristics determining the choice of parents for the crossing program are:

- Resistance to diseases and pests
- Large seed size
- Light colored seed
- Time to maturity.

Selection

In the 1991/92 crop season, over 300 individual plants with light seed color and high pod number were selected from ICRISAT's observation nursery and from nurseries grown by the national program at Chitedze, Malawi. In 1992/93, bulk seed of the 20 best selections was used to prepare the 1992/93 Regional Observation Nursery. The remaining selections were evaluated in single-row plots in the Individual Plant Selection Nursery.

In 1993/94, 12 entries from these two nurseries were used to form the 1993/94 Regional Long-duration Preliminary Pigeonpea Yield Trial. In another study in 1993/94, a total of 127 individual plants were selected in the germplasm and breeding nurseries for seed size, seed color, and number of seeds per plant. While selecting these genotypes, considerable emphasis was given to selecting individual plants showing tolerance to drought. Of the 127 selections, 57 were chosen to be evaluated in a non-replicated 4-row plot observation nursery at two or more locations in drought-prone areas. All the selected plants had white seeds; seed size (100-seed mass) and seed number are shown in Table 2.

Table 2. Seed size and seed number plant[1] in 127 pigeonpea selections, Malawi, 1993/94.

100-seed mass (g)	Number of selections[1]	Seed number $plant^{-1}$	Number of selections
<11	7(6)	<200	18(14)
11.1-13	42 (33)	201-500	53 (42)
13.1-15	56 (44)	501-800	34 (27)
15.1-18	18(14)	801-1200	18(14)
>18.1	4(3}	>1200	4(3)
Total	127		127

1. Figures in parentheses show percentage of total nuber of selections.

Breeding for seed size and seed color

A modified bulk-breeding method is used to develop genotypes with large, light-colored seeds. The desirable plants from F_2 through F_5 generations are bulk-harvested. After threshing, seeds are sieved through a 5 mm mesh screen, and light-colored seeds larger than 5 mm in size are included in the trial/nursery.

During the 1991/92 growing season, 15 single crosses were made at random within genotypes with different agronomic characters and maturity durations (Table 3). F_1s and F_2s of these crosses were grown at Chitedze during the 1992/93 and 1993/94 growing seasons, and the resulting seed harvested in bulk to prepare the 1994/95 F_3 population trials. Seeds of the F_3 populations will be supplied to collaborators who wish to make their own selections at specific locations.

Breeding for wilt resistance

One way to increase production of pigeonpea is by growing wilt-resistant genotypes. The primary feature of this Project is the introgression of genes for resistance to diseases from non-adapted to adapted (local) germplasm. During the 1992/93 growing season, we made crosses between ICP 9145 (wilt-resistant) and 30 cultivars/lines (17 local cultivars, 7 short-duration, and 6 medium-duration lines) to transfer resistance genes from ICP 9145 to these genotypes (Table 4). F_1s of these crosses were grown at Chitedze for making back-crosses and for advancement to F_2s. In the 1994/95 season, bulks of the F_2 seed will be advanced to F_3 at Chitedze and screened for wilt resistance at Bunda and Bvumbwe.

Backcross breeding is used to improve the landraces. The major emphasis is on the introgression of genes for resistance to wilt from ICP 9145 to landraces and elite exotic lines (Table 5). During the 1993/94 season, 23 F_1s from crosses between ICP 9145 and 17 landraces and ICP 9145 and 6 medium-duration pigeonpea lines were back-crossed to the parents to incorporate more of the desired genes into the crosses.

Table 3. Pigeonpea crosses made during the 1991/92 season at Chitedze, Malawi.

SD x MD[1]	SD X LDWR	Local x LDWR
ICP 8805 x QP 14	ICPL 87 x ICP 9145	PGM 9209 x ICP 9145
ICP 8858 x Royes	ICPL 151 x ICP 9145	PGM 9215 x ICP 9145
ICP 8859 x HY 3C	ICPL 269 x ICP 9145	PGM 9218 x ICP 9145
ICP 8863 x QP 38	ICPL 86005 x ICP 9145	
SPMA 6 x QP 14		
SPMA 6 x Line 21		
ICPL 87 x Royes		
BWR 254 x Royes		
Number of crosses 8	4	3

1. SD/MD = Short/medium-duration, LDWR = Long-duration wilt-resistant

Table 4. Local, short-duration, and medium-duration pigeonpea lines crossed with wilt-resistant, long-duration ICP 9145, Chitedze, Malawi, 1992/93 season.

LDWR x Local		LDWR x SD	LDWR x MD[1]
PGM 9201	PGM 9215	ICPL 87	QP14
PGM 9202	PGM 9217	ICPL146	QP15
PGM 9204	PGM 9218	ICPL 151	QP37
PGM 9207	PGM 9219	ICPL 267	QP38
PGM 9208	PGM 9226	ICPL 269	HY3C
PGM 9209	PGM 9229	ICPL 86005	Royes
PGM 9210	PGM 9232	ICPL 86105	
PGM 9213	PGM 9233		
PGM 9214			
Number of crosses	17	7	6

1. LDWR = long-duration wilt-resistant ICPL9145, SD/MD = short/medium-duration.

Table 5. List of 3-way crosses made during the 1993/94 season at Chitedze, Malawi

Pedigree	Number of successes
(ICP 9145 x PGM 9201) x PGM 9201	42
(ICP 9145 x PGM 9202) x PGM 9202	31
(ICP 9145 x PGM 9204) x PGM 9204	18
(ICP 9145 x PGM 9207) x PGM 9207	27
(ICP 9145 x PGM 9208) x PGM 9208	5
(ICP 9145 x PGM 9209) x PGM 9209	23
(ICP 9145 x PGM 9210) x PGM 9210	30
(ICP 9145 x PGM 9213) x PGM 9213	49
(ICP 9145 x PGM 9214) x PGM 9214	18
(ICP 9145 x PGM 9215) x PGM 9215	12
(ICP 9145 x PGM 9217) x PGM 9217	34
(ICP 9145 x PGM 9218) x PGM 9218	10
(ICP 9145 x PGM 9219) x PGM 9219	6
(ICP 9145 x PGM 9226) x PGM 9226	18
(ICP 9145 x PGM 9229) x PGM 9229	24
(ICP 9145 x PGM 9232) x PGM 9232	25
(ICP 9145 x PGM 9233) x PGM 9233	56
(ICP 9145 xQP 14)xQP 14	55
(ICP 9145 xQP 15)xQP 15	10
(ICP9145 x QP 37)xQP37	45
(ICP 9145 x QP 38) x QP 38	25
(ICP 9145 xHY3C)xHY3C	46
(ICP 9145 x Royes) x Royes	23

In 1994/95, part of the F_1 seed from the crosses will be advanced to F_2 at Chitedze, and the remaining will be screened for wilt resistance at Bunda.

Resistance to leaf spot disease

Leaf spot is a very serious disease, especially in high-rainfall areas in Africa. In the 1992/93 season, 1198 germplasm accessions collected from 47 countries were evaluated for resistance to *Cercospora* leaf spot at Chitedze, Malawi, using a 1-9 scale (1 = highly resistant, 9 = highly susceptible). Of the 1198 accessions, 13 rated 2, 34 rated 3, and 44 rated 4, and the remaining 1107 rated between 5 and 9. A total of 90 selections with ratings of 2 and 3 (47 selections from the germplasm and 43 from the Individual Plant Selection Nursery) were chosen for further evaluation. In the 1993/94 season, a nursery consisting of these 90 entries and a susceptible control was grown at Chitedze, and *Cercospora* resistance evaluated using the infector-row technique.

Infected leaf debris collected from the 1992/93 season was scattered in the field to serve as a primary inoculum source. Unfortunately, disease severity was too low to evaluate genotypic differences. Therefore, the trial will be repeated in 1994/95.

Breeding for wide adaptation

Currently, we are evaluating elite germplasm and advanced breeding lines for adaptation and other desirable agronomic traits at several locations in many countries in the region. Yield performance, correlation, and regression studies are used to compare the performance of entries in different environments. High-yielding entries with good agronomic traits are selected for further evaluation and/or inclusion in the breeding program for further improvement.

During the past 2 years, 10 short-duration lines were tested in 15 environments in the region (Table 6). Six entries gave higher yields than the control (ICPL 87). ICPLs 90029 (1.65 t ha^{-1}); 86005 (1.6 t ha^{-1}), and 90028 (1.5 t ha^{-1}) had the highest overall location mean yields, indicating their wide adaptability. We further examined these three entries using a stability analysis, where location mean yields were plotted against the variety yields at each location (Fig. 1). The three entries showed little or no difference at locations where location means were low, but differences were observed in areas with high location means. Although ICPL 90028 yielded less than ICPL 86005 and ICPL 90029, it showed much lower regression values, indicating better stability than the other two.

Future plans

Breeding. The present activities will continue, but more emphasis will be given to the development of drought-tolerant genotypes. In addition, we will be supplying F_3

Table 6. Grain yields (t ha^{-1}) of 10 pigeonpea lines across 15 environments in 5 countries, 1993/94.

Genotype	Swaziland		Zam[1]	Nam	Malawi						Kenya					Mean across loca-tions	Rank
	Les	Luve	Mse	Mah	Chi 1992	Chi 1993	Mak 1992	Mak 1993	Ngabu 1993	Baka 1993	Kibw 1992	Kibo 1992	Kibo 1993	Kan 1993	Kab 1993		
ICPL 90029	0.64	0.18	0.54	0.27	2.14	0.97	2.14	1.06	0.15	1.48	3.96	4.94	3.27	1.21	1.86	1.65	1
ICPL 86005	0.88	0.36	0.62	0.26	2.87	0.52	1.63	1.13	0.17	0.44	3.92	4.49	3.43	1.07	2.22	1.60	2
ICPL 90028	0.68	0.24	0.22	0.24	2.87	1.00	2.41	1.51	0.25	1.38	2.62	3.52	2.51	1.34	1.79	1.50	3
ICPL 87101	0.97	0.15	0.61	0.33	2.70	0.31	1.46	1.05	0.09	1.33	3.67	3.93	3.11	0.85	1.63	1.48	4
ICPL 87105	0.66	0.13	0.58	0.29	2.15	0.66	1.50	0.99	0.23	1.21	3.60	3.43	2.94	0.64	1.98	1.36	5
ICPL 87104	0.88	0.29	0.45	0.24	1.71	0.65	1.70	1.06	0.29	0.79	2.71	2.61	2.62	1.15	1.75	1.26	6
ICPL 87	0.70	0.22	0.35	0.26	1.69	0.16	1.43	0.87	0.28	0.94	2.76	2.84	3.01	0.72	1.86	1.21	7
ICPL 86012	0.77	0.30	0.61	0.28	1.50	0.53	1.91	0.89	0.52	1.04	2.60	2.59	2.12	0.84	1.40	1.19	8
ICPL 88027	0.75	0.31	0.10	0.28	2.66	0.12	1.35	1.13	0.25	1.29	2.32	2.49	2.42	1.12	1.09	1.18	9
ICPL 90024	0.54	0.35	0.36	0.28	1.71	0.53	1.51	0.96	0.60	1.31	2.20	2.23	1.95	0.80	1.44	1.12	10
Mean	0.74	0.26	0.44	0.27	1.74	0.52	1.51	1.07	0.28	1.15	3.01	3.32	2.79	0.97	1.70		

1. Zam = Zambia, Nam = Namibia, Mse = Msekera, Mah = Mahanene, Chi = Chitedze, Mak = Makoka, Kibw = Kibwezi, Kibo = Kiboko, Kab = Kabete, Kan = Kanyiya.

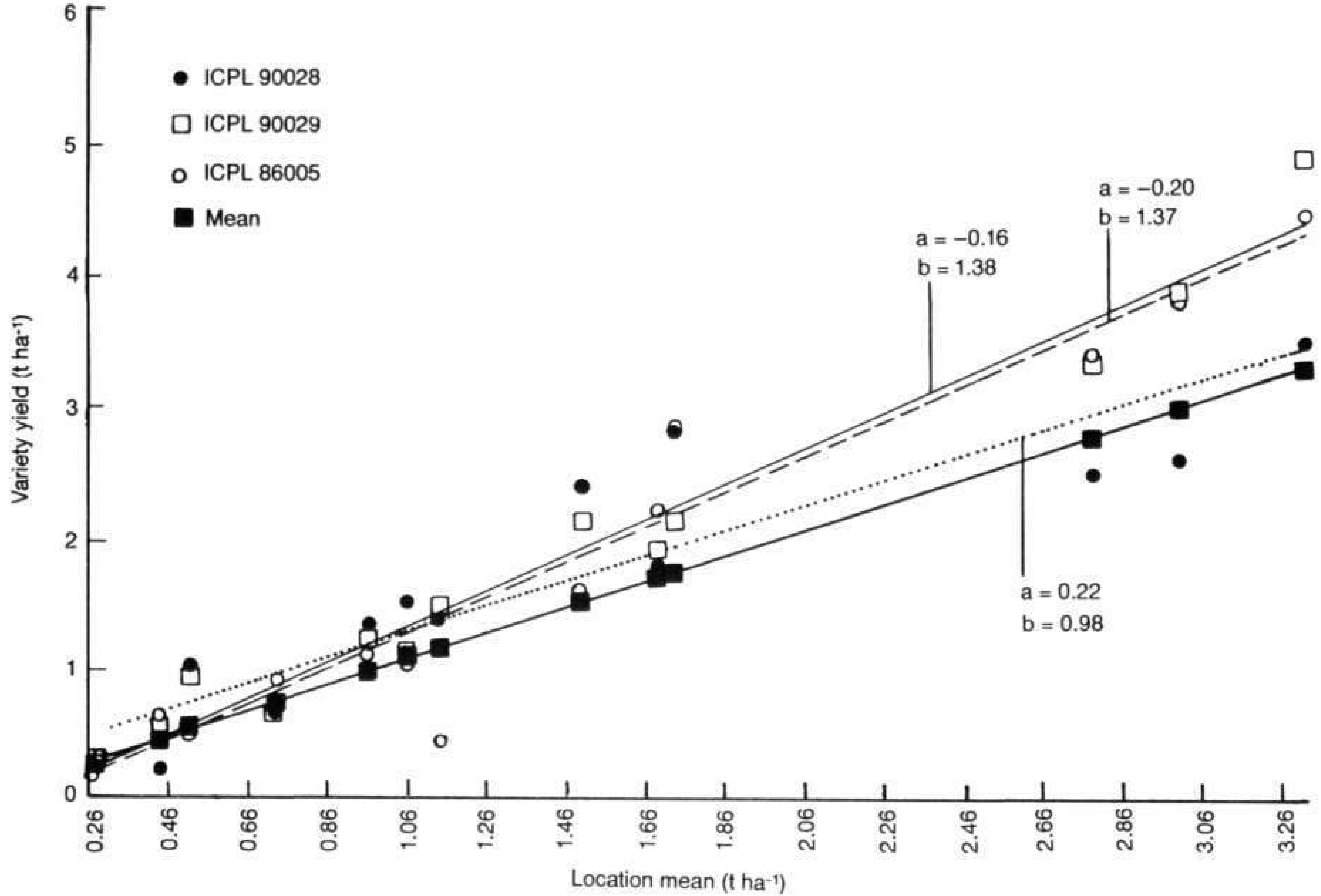

Figure 1. Stability analysis of three pigeonpea varieties, Pigeonpea Variety Trial 1993/94.

segregating population trials to breeders interested in making their own selections for specific environments.

Agronomy. In collaboration with NARS, NGOs, and other organizations, we will be conducting several on-farm trials, especially in countries where pre-release pigeonpea varieties are available. We will also identify commercial farmers who are willing to handle pilot demonstration plots of short-duration pigeonpea. The development of national seed multiplication and distribution programs is a key issue. We will therefore collaborate in supplying breeders' seed to NARS, and will increase seed of elite germplasm and breeding material during the growing season and/or off-season. We will develop agronomy packages for short-duration pigeonpea.

Diseases. We will strengthen the collaborative work on diseases at Bunda and Bvumbwe by:

- Further developing the existing sick plots at these two locations to improve accuracy and handle more material
- Developing basic student research proposals on pigeonpea in collaboration with universities.

Training for technicians. The project will organize a short-term training course for technicians involved in pigeonpea research and development. The main objectives of the training are to:

- Provide a basic knowledge of pigeonpea botany, pests, and agronomy to technicians who handle the crop daily
- Maintain uniformity and accuracy in data collection and analysis.

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Pigeonpea Improvement in Uganda

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Introduction

Pigeonpea is one of the major food legumes cultivated in Uganda. It is grown mainly for its grain, which is eaten as whole seed in green or dry form, or as dry split seed cooked to form a homogeneous paste. Pigeonpea is also important in the farming system, enriching the soil when used as a rotation or mixed crop. The plant is also a source of fuel, animal feed, and construction material, and can serve as a wind-break and to prevent soil erosion.

Production

Despite the many uses of pigeonpea and its long history of cultivation in Uganda, production has remained low and restricted to some areas only, where it is often grown as a subsistence crop. Pigeonpea is grown mainly in northeastern and northern Uganda, in the districts of Gulu, Kitgum, Nebbi, Lira, Apac, and Soroti. It is also produced elsewhere in the country, but as a backyard crop with only a few stands.

The crop is grown rainfed, with minimal inputs. It is usually mix-cropped with cereals (mainly millet) and groundnut, making it difficult to accurately estimate production and productivity figures. The National Agricultural Research Organization in Uganda has set targets of 40% yield increase (part of which will come from new technology) and 20% adoption rate. Demand from consumers and farmers is expected to increase once improved varieties and production packages are made available to farmers.

Production constraints

Pigeonpea production is hampered by a number of constraints.

Lack of improved varieties. Smallholder farmers, who are the main producers, continue to grow low-yielding (250-400 kg ha^{-1}) unimproved local cultivars. These cultivars are mainly long-duration types (over 9 months to maturity); some are medium-duration types (over 6 months). Farmers are therefore unable to grow two crops in a year.

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Lack of good-quality seed. There is no system for the production of certified seed. Farmers often save their own seed from the previous season's harvest or buy some from the market. This results in mixtures with poor quality seeds. Storage pests are also a problem (storage facilities are often poor) and the seed is often badly damaged, giving poor, unhealthy plants.

Insect pests. Pigeonpea is attacked by a range of pests at all stages of growth. The most destructive are those that attack the crop during the reproductive phase and in storage. Insecticides are rarely used, and consequently total crop failure sometimes occurs, while storage losses are frequent and often severe.

Diseases. These are not very serious, but wilting has been observed, as also powdery mildew and leaf spots.

Weeds. Pigeonpea is often intersown with finger millet. The millet crop is weeded (only once), but pigeonpea is not. In addition, there is no proper row arrangement, seed being usually broadcast. The finger millet continues acting as a weed on the pigeonpea throughout the vegetative and reproductive phases, reducing pigeonpea yields.

Poor marketing system. There is no proper marketing system for the crop. Farmers thus produce pigeonpea mainly for home consumption, and just a little more for sale at the local market, where price is not guaranteed.

Poor utilization options. The lack of processing facilities and of diversified utilization options has limited adoption of the crop in non-traditional pigeonpea-growing areas. Areas where pigeonpea has traditionally been used continue to be the main production centers.

Improvement strategies

Data from a preliminary survey indicate that the most important varietal characteristics in terms of farmers' needs are: early/medium maturity, high grain yield, large white/cream seeds, quick cooking, and resistance to insect pests. Accordingly, the objectives of the breeding program are to:

- Widen the genetic base of breeding materials to facilitate selection of superior lines
- Develop improved, high-yielding, medium-duration varieties with acceptable grain qualities, suitable for existing farming systems
- Develop short-duration, high-yielding varieties with acceptable seed characters, suitable for monocropping
- Identify genotypes with resistance to biotic and abiotic production constraints.

These objectives are being addressed in several ways:

- Establishing linkages with pigeonpea-producing countries, NARS, and international research institutes (e.g., ICRISAT) for procurement of breeding material
- Collecting and evaluating local cultivars to select parents for the hybridization program
- Evaluating foreign accessions to identify genetic sources of resistance and desirable traits not available in local cultivars
- Screening breeding lines to select improved lines with high yield potential
- Multilocational evaluation of promising lines to study genotype x location interactions
- Strengthening research-extension-farmer linkages through on-farm trials and workshops.

Germplasm collection

During the 6 years of civil strife in eastern and northern Uganda, all the pigeonpea breeding lines and germplasm were lost. Efforts were then made in 1992 to procure germplasm and reactivate pigeonpea research. Local and foreign accessions were procured: 249 accessions from ICRISAT, and 43 local accessions collected within the country. Evaluation and characterization of this material will be done in 1994.

Yield trials

Several sets of trials were received from ICRISAT and EARCAL. Three trials (on extra short, short-, and medium-duration genotypes) were conducted. The results are reported below.

EARCAL Short-duration Varietal Trial

Twelve entries were evaluated in a randomized complete block design with three replicates. Plots consisted of 8 rows, each 5 m long, thinned to 1 plant $hill^{-1}$. Spacing was 40 x 10 cm. Harvesting was done on the six inner rows, discarding the outermost rows and 50 cm at each end of the harvested rows (net plot size 4 m x 2.4 m). The results are shown in Table 1.

This trial was sown rather late (late Jun 1993), during a dry spell at the end of the first rainy season. As a result, germination, gap filling, and final plant stand were poor. Except for Kat 60/8 all the entries showed determinate growth, flowered within 2 months, and reached maturity in a little over 3 months. Seed yields were satisfactory. The highest yielder was ICPL 90029 (2.55 t ha^{-1}), and two other lines yielded >2 t ha^{-1}. Kat 60/8 (indeterminate type) performed very poorly. It was the slowest to maturity and gave the lowest yield, although it grew taller than the other cultivars in

Table 1. Performance of 12 genotypes in the EARCAL Short-duration Pigeonpea Varietal Trial, Serere Research Station, Uganda, 1993.

Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant stand at harvest	Seed yield[1] (t ha^{-1})
ICPL 90029	54.0	92.7	59.7	101.0	2.55
ICPL 87101	53.7	93.0	62.2	97.3	2.24
ICPL 151	57.0	94.3	52.9	61.6	2.03
ICPL 87091	58.0	97.0	70.7	94.7	1.99
ICPL 87 B	53.0	94.3	55.1	95.7	1.97
ICPL 90028	55.3	95.7	48.1	81.3	1.92
ICPL 87 W	53.0	94.0	60.6	106.3	1.82
ICPL 87102	53.6	95.3	58.9	92.3	1.77
ICPL 86005	54.0	93.0	73.2	118.0	1.56
ICPL 83016	59.7	97.0	69.8	80.7	1.51
ICPL 87104	53.3	92.3	53.9	128.7	1.42
Kat 60/8	69.0	110.0	75.5	92.7	0.48
Mean	56.1	94.6	61.7	95.9	1.77
LSD at P 0.05	3.2	3.05	ns	32.3	0.98
CV(%)	3.4	1.7	20.6	19.9	30.8

1. Seed yield adjusted using covariance technique, because of poor plant stand,
ns = not significant.

the trial. The low yield was due to heavy pest attack by blister beetles, which chewed up virtually all the floral parts. Kat 60/8 is already being evaluated in on-farm trials.

Medium-duration Pigeonpea International Trial

Sixteen genotypes obtained from ICRISAT were evaluated in a randomized block design with three replicates. The trial was sown in late Jun 1993. Plots were 4 m x 3 m, consisting of 4 rows of 4 m length. Spacing was 75 x 20 cm. Net plot size was 5.4 m^2 (the two middle rows were harvested, after discarding 20 cm from each end).

This trial was similarly affected by drought at the time of sowing, and final plant stands were poor. No significant differences between varieties were observed in days to maturity (mean 130.2, range 126-135) or in seed yield (mean 2.38 t ha^{-1}, range 1.55-4.32 t ha*[1]). However, these yields (figures adjusted using the covariance analysis technique) are far superior to yields obtained from local cultivars in farmers' fields. These varieties are generally small-seeded, with red or brown seeds. Farmer acceptability may therefore be a problem. The varieties will, however, be useful in the improvement of local cultivars.

Extra Short Duration Pigeonpea International Trial

Eighteen varieties from ICRISAT were sown in late Jun 1993 using a randomized block design, replicated three times. Plots consisted of four rows 4 m long, with a spacing of 30 x 10 cm. Due to poor plant stand the whole plot was harvested.

As in the previous trial, no significant differences were seen among cultivars in days to maturity (107-112, mean 110), 100-seed mass (8.3-10 g, mean 9.6), or seed yield (1.85-3.73 t ha^{-1}, mean 2.58 t ha^{-1}, adjusted using covariance analysis). While the yields were impressive, seed size and color of these lines may not be acceptable to farmers. However, this material will be used by the breeding program to improve local medium- and long-duration cultivars.

Effect of Spacing on Yield of Two Pigeonpea Cultivars in Uganda

J E Obuo and H Okurut-Akol[1]

Introduction

Pigeonpea *(Cajanus cajan)* is an important grain legume crop in Uganda, especially in the northern and eastern parts. It is also grown to some extent in West Nile and Bunyoro, and in small quantities (usually on homesteads) in southern Uganda. Pigeonpea is the dominant legume crop in the districts of Gulu, Apac, Lira, and Kitgum, where it is a major source of protein.

Despite the various important attributes of pigeonpea (e.g., drought tolerance, nitrogen fixation, protein content), yields are low and production is declining in Uganda. Cropped area fell from 121 000 ha in 1972 to 63 000 ha in 1985, and production from 48 000 t to 22 000 t in the same period (MoA 1987). This decline, which is still continuing, is due to pest problems, lack of improved varieties, and poor agronomic practices such as poorly timed and/or inadequate weeding and inappropriate plant populations. The loss of oxen during the period of unrest means that cultivation is done mainly with hand hoes. This has led to a severe shortage of labor.

To increase pigeonpea production and yield it is necessary to identify high-yielding varieties suitable for intercropping with finger millet, and develop recommendations on optimum spacing and cropping systems, for example to suppress weed growth and thus alleviate the problem of labor shortages.

Among the various factors that influence the growth and yield of legume crops, spacing is considered important, particularly where labor is a limiting factor. In some cases, narrow spacing (Grafton et al. 1988) and high sowing density have tended to increase the seed yield of some legume crops. However, information on optimum spacing for pigeonpea is lacking in Uganda. The objective of this investigation was to determine the effect of interrow and within-row spacing on pigeonpea yield and establish the optimum spacing for two promising cultivars, ICPL 87091 and Kat 60/8, that are scheduled to be tested on-farm and perhaps subsequently released to farmers.

Materials and methods

The experiment was conducted during the second rainy season of 1993 at the Serere Agricultural and Animal Production Research Institute in northeastern Uganda. Two cultivars, ICPL 87091 (received from EARCAL/ICRISAT, Kenya) and Kat 60/8, were sown on 2 Oct 1993. Three sprays of Decis® (sulphamethoate) were applied to

1. Serere Agricultural and Animal Production Research Institute, P O Soroti, Uganda.

control pests. No fertilizers were applied, and only normal agronomic practices (e.g., weeding and thinning) were followed. The plants were thinned to one plant per hill.

Five interrow spacings (60, 50, 40, 30, and 20 cm) and two within-row spacings (30 and 10 cm) were used, giving populations of 55 556, *66* 667, 83 333, 111 111, 166 667, 200 000, 250 000, 333 333, and 500 000 plants ha^{-1}. A randomized complete block design was used with three replications. Plot size was 4.2 x 3.6 m. Yield was determined by harvesting the two middle rows from each plot. In each plot, mean number of branches and pods was obtained from five plants selected at random from the two middle rows, and the plot average calculated. The data were subjected to analysis of variance (ANOVA) with appropriate single degrees of freedom.

Rainfall was lower than in previous years, and this to some extent could have affected yields in the experiment.

Table 1. Yield and yield components of two pigeonpea genotypes grown at different spacings, Serere Research Farm, Uganda, 1993.

Spacing	Number of branches $plant^{-1}$	Plant dry. weight (kg)	Number of pods $plant^{-1}$	Yield ($t\ ha^{-1}$)
ICPL 87091				
60 x 30 cm	5.33	0.50	29.67	0.89
50 x 30 cm	4.67	0.55	23.33	0.99
40 x 30 cm	5.00	0.62	20.33	0.98
30 x 30 cm	4.67	0.63	25.67	1.09
20 x 30 cm	3.00	0.75	21.00	1.29
60x10 cm	4.00	0.78	19.67	1.23
50x10 cm	3.00	0.84	20.67	1.45
40x10 cm	3.00	1.05	19.00	1.58
30x10 cm	3.33	1.08	17.33	1.72
20x10 cm	3.33	1.12	13.33	1.82
LSD (0.05)	1.98	0.32	6.24	0.712
CV(%)	29.40	23.7	17.32	31.87
Kat 60/8				
60 x 30 cm	5.33	0.53	44.67	0.72
50 x 30 cm	4.67	0.63	33.00	0.79
40 x 30 cm	3.33	0.54	29.00	0.83
30 x 30 cm	4.33	0.95	24.00	1.52
20 x 30 cm	3.33	0.72	21.00	1.27
60 x 10 cm	3.00	0.76	23.00	1.43
50x10 cm	2.67	0.78	22.00	1.05
40x10 cm	2.57	0.85	20.00	1.36
30 x 10 cm	3.00	1.02	19.00	1.63
20x10 cm	2.13	0.79	12.67	1.05
LSD (0.05)	1.865	0.523	10.23	0.761
CV(%)	30.48	25.52	26.03	30.01

Results and discussion

Results are summarized in Table 1. For both ICPL 87091 and Kat 60/8, wider interrow and within-row spacings resulted in higher seed yields and lower mean number of branches and pods.

There were significant differences in the number of branches and pods per plant as the spacing changed. It appeared that wide spacing encouraged branching and pod filling, probably because the space and resources were sufficient for both vegetative growth and pod filling. Within-row spacing had a more significant effect than interrow spacing on the number of branches and pods produced. This was perhaps because competition between plants within a row was more intense than competition between rows. These results agree with earlier studies (e.g., Bennett et al. 1977), which reported that an increase in plant population reduces the number of pods $plant^{-1}$ but could improve seed yield.

The relationship between yield and spacing was more marked (significant difference at P = 0.05) in ICPL 87091 than in Kat 60/8, probably because of the difference in growth habit of these cultivars. The yield increase at high density could possibly be due to more effective use of resources by the plant, with the assimilates being converted into grain instead of vegetative parts. Response to narrow spacings resulted in yield increases of 50% in Kat 60/8 and 20% in ICPL 87091, when compared to yields at conventional spacings (60 x 30 cm for Kat 60/8, 40 x 10 cm for ICPL 87091). It is thus possible to increase pigeonpea yields by using closer spacing, which in addition is beneficial in suppressing weed growth.

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Recent Research on Pigeonpea in Uganda

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Introduction

In the major pigeonpea-growing areas in Uganda, farmers grow long-duration varieties (8-12 months) mix-cropped with millet (MAAIF 1992). Yields are generally low. Short-duration varieties can help increase productivity, and also permit farmers to raise two crops a year. Long-duration varieties are popular in low-rainfall areas (e.g., in northern Uganda). It would be beneficial to promote suitable short-duration cultivars in these regions, once their performance has been established.

Pigeonpea-millet intercropping

In the major growing areas in Uganda, pigeonpea is intercropped mostly with millet, and to a lesser extent with groundnut, maize, cassava, sorghum, etc. The current practice is to sow pigeonpea in widely spaced rows, and broadcast millet. Low population density of pigeonpea has been a major reason for the low pigeonpea yields in a millet intercrop, but information on appropriate pigeonpea density is not available. In this study we used the traditional system (pigeonpea sown in rows, millet broadcast) with different pigeonpea spacings, to determine the optimum for this intercrop.

Materials and methods. These were reported earlier by Musaana and Njogedde (1994).

Results. The trial was sown in late May, using local varieties of both pigeonpea (long-duration) and millet. Data will be collected on days to 50% flowering and maturity, yield, and yield components. The results will be reported next season.

On-farm research and demonstration in northern Uganda

Twelve pigeonpea demonstration trials were sown in Jun 1994 (7 in Lira district, 5 in Apac district) to compare two short-duration varieties, Kat 60/8 and ICPL 87091, with the local varieties. The trials will be harvested shortly, after which postharvest evaluation will be conducted jointly by farmers and researchers.

1. Namulonge Agricultural and Animal Production Research Institute, P O Box 7084, Kampala, Uganda.
2. ICRISAT Pigeonpea Project, P O Box 39063, Nairobi, Kenya.

Apart from the demonstrations, during our survey in 1992, we distributed seed of Kat 60/8 (200-300 g per farmer) to a number of farmers in Gulu, Lira, and Apac districts. The variety is performing very well; during our last visit we found that one farmer in Lira had sown 0.8 ha of Kat 60/8 on his farm. This is a good indication that the newly developed varieties can become popular. We plan to make a follow-up visit in Dec 1994 to more accurately assess how far the adoption of these varieties has progressed.

Spacing and moisture stress in short-duration pigeonpea

In this study, we aimed to determine the most appropriate seedling densities for two short-duration varieties (ICPL 87091 and Kat 60/8) under moisture stress or a low-rainfall regime.

Materials and methods. Two short-duration pigeonpea varieties, ICPL 87091 and Kat 60/8, were sown at Kawanda Agricultural Research Institute (KARI) and Ngetta Experimental Station (NES) during the second rainy season of 1993. These were sown at spacings of 30 x 10 cm, 45 x 10 cm, 60 x 10 cm, and 75 x 10 cm in a randomized complete block design. Sowing dates were 21 Sep at NES and 9 Oct at KARI, deliberately delayed to induce moisture stress (normal sowings are in Jun). Harvesting was done in late Jan (NES) and mid Feb (KARI). Each site was weeded three times and sprayed twice.

The data collected included rainfall amount and distribution, days to 50% flowering, plant height at 50% flowering, plant height at maturity, number of pods, damaged pods and seeds plant^{-1}, seed weight plant^{-1}, and dry pod weight and grain yield ha^{-1}. Analysis of variance (ANOVA) was performed on the data. Preliminary results (for one season only) are reported here.

Results and discussion. There was no significant difference between treatments for plant height at 50% flowering/maturity, days to 50% flowering, number of seeds/damaged pods plant"^{1}, and seed weight plant^{-1}. However, at both sites, there was tendency for ICPL 87091 to be taller and flower and mature earlier than Kat 60/8. This difference was more pronounced at KARI.

At NES, spacing (but not variety) had a significant effect on number of pods plant-^{1}. The average number of pods plant-^{1} at NES was 25 for Kat 60/8 and 21 for ICPL 87091. At KARI it was much lower (13 for Kat 60/8 and 10 for ICPL 87091). This could be due to the dry weather, which could have led to flower abortion. Dry pod weight was not significantly different for the different spacings, except at 30 x 10 cm in ICPL 87091 and 75 x 10 cm in Kat 60/8 (Table 1). Although the data are not conclusive, there are indications that for these two varieties, narrower spacing would be more advantageous than wider spacings.

Grain yield was not significantly affected by variety or spacing at KARI, but was significantly affected by spacing at NES (e.g., Kat 60/8, Table 1). Shelling percentage

Table 1. Performance of two short-duration pigeonpea cultivars at different spacings, Ngetta Experimental Station, Uganda, second rains 1993.

Genotype	Spacing	Number of pods plant"1	Pod dry weight (t ha1)	Grain yield (t ha1)	Shelling percentage
ICPL 87091	30 x10 cm	15b	1.02 a	0.60 a	59
	45 x10 cm	19 ab	0.82 a	0.50 ab	61
	60 x10 cm	27 ab	0.92 ab	0.58 a	63
	75x10 cm	25 ab	0.90 ab	0.57 a	64
Kat 60/8	30 x10 cm	17 ab	0.92 a	0.49 ab	53
	45x10 cm	37 a	0.86 ab	0.57 a	66
	60x10 cm	24 ab	0.92 ab	0.53 ab	58
	75 x 10 cm	24 ab	0.64 a	0.36 b	57
CV(%)		27.3	16.1	18.3	
Level of significance		*	•	•	ns

* Significant at 5% level using LSD.
ns = not significant.
Means for a given parameter, when followed by the same letter, are not significantly different.

was higher at NES than at KARI, but at neither location were there significant differences among the eight treatments.

From these preliminary results, NES would seem to be a better location than KARI for growing pigeonpea. The data also suggest that at NES the number of pods plant*1 increases at higher spacings, while grain yield decreases.

A number of factors could have contributed to the low yields at the two sites, including uneven rainfall distribution, which could have led to flower abortion. There was also heavy infestation of aphids, especially at KARI. Otherwise, the two varieties have shown the potential to produce well under moisture stress. More work is required to be done on spacings for these varieties, and on the effect of moisture stress on flower abortion and pest incidence.

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Non-chemical Methods of Pigeonpea Storage Pest Management

M Silim-Nahdy[1]

Introduction

Bruchids are the most serious pests of stored grain legume seed. Various species of bruchids have been reported as infesting stored pigeonpea seeds. The most serious of these, however, belong to the genus *Callosobruchus.* In eastern Africa, C. *chinensis,* C. *maculatus,* C. *rhodesianus,* and C. *analis* have been reported, the latter two from Tanzania (Mphuru 1978). Surveys in 1993 indicated that C. *chinensis* was the most serious pest of stored pigeonpea in Uganda (Silim-Nahdy and Odong 1994).

Because grain legumes are highly susceptible to bruchid damage, various pest management methods—mainly 'in-storage' seed treatment—have been attempted. These have met with varying levels of usage and success. The more modern pest control options (insecticides and fumigants), though very effective, are often beyond the reach of resource-poor farmers in developing countries (Kitch et al. 1992). Moreover, most of the stored grain is consumed by the farmer, and therefore the use of hazardous insecticides is normally unacceptable (Khaire et al. 1992). In addition, many strains of pests are resistant to a broad range of insecticides. Many non-chemical management practices used by farmers have been recorded, but most have not been documented or are of unproven effectiveness.

The present work is the result of a series of studies which identified the major storage problem as damage by C. *chinensis.* The studies focused on several aspects: identification of on-farm pests, pest distribution and the magnitude of losses, and biotic and abiotic determinants of pest infestation. The results will be used to develop management options suitable for on-farm use. In this report, three management options are reported in some detail, and others mentioned briefly. The management options investigated were:

- Field insecticide spraying
- In-pod storage
- Sealed storage
- Other options.

Effect of field spraying on C *chinensis* damage in storage

Materials and methods. Pigeonpea variety Kat 60/8 was sown on 4 m x 3 m plots in a randomized complete block design. A guard row 1 m wide was sown with maize

1. Post-harvest Programme, Kawanda Agricultural Research Institute, P O Box 7065, Kampala, Uganda.

to minimize insecticide drift during spraying. Two treatments, sprayed and unsprayed, were replicated four times. Insecticide was sprayed four times, beginning at 50% flowering, and thereafter at 10-day intervals, using cypermethrin Ambush® (5% EC), diluted to 0.5%, @ 200 L ha^{-1}.

At maturity, pods in each plot were harvested, and hand-sorted into *Helicoverpa armigera* damaged and undamaged pods. After counting, the damaged and undamaged pods from each plot were mixed and shelled. Seeds from each plot were standardized into 250 g lots using a Boerner divider. Each lot was separately incubated in 250 mL glass jars for 2 months. At monthly intervals, emerging insects from each jar were sieved out, identified, counted, and all live insects put back. The damaged seeds were also sorted and weighed, and percentage damage calculated.

Results and discussion. Field damage by *H. armigera* was significantly (P=0.005) reduced by spraying, from 10.7% damage in unsprayed to 1.1% in sprayed fields. Spraying seemed to have equally reduced field infestation by C. *chinensis* and thus reduced seed damage and pest population in storage (Table 1).

Pest population and seed damage measured after 1 and 2 months in storage were significantly lower in sprayed pigeonpea than in produce from unsprayed plots. The results confirm earlier findings (Silim-Nahdy and Odong 1994) that C. *chinensis* infestation is mostly of field origin. Field insecticide treatment could therefore be recommended; this would control pest damage both in the field and in storage. Further investigations are needed to determine optimal spraying regimes and the most effective insecticides.

Pod storage for C *chinensis* control

Materials and methods. Pigeonpea pods of the local variety Adyang from Gulu district were hand-harvested and used for the trials. Two hundred kg of pods were thoroughly mixed, placed in gunny bags, and fumigated at a dosage rate of 50 g t^{-1} under a gas-tight fumigation sheet for 96 h. By conning and quartering, the pods were divided, first into two 100-kg treatment lots, and further into four 25-kg treatment

Table 1. *Callosobruchus chinensis* emergence and seed damage in stored pigeonpea originating from insecticide-treated and untreated plots, Kawanda Agricultural Research Institute, Uganda, 1993/94.

Storage duration	Mean number of emerged insects		Seed damage (%)	
(months)	Treated	Untreated	Treated	Untreated
1	3.00	19.67	0.18	1.23
2	68.80	633.00	5.08	29.25

replicates. The two treatments were: unshelled 'in-pod' storage in open, traditional reed granaries, and shelled 'seed' storage in cloth bags.

During shelling of the 'seed storage' sub-lots all adult C. *chinensis* were recorded and percentage seed damage determined from a representative 200 g sample. This was done to determine initial infestation and seed damage (before storage).

Each sub-lot was infested with 24 pairs of 24-h old adult C. *chinensis* and stored for 2 months. At the end of the storage period the pod and seed sub-lots were sieved and the number of emerged adult C. *chinensis* counted. For the seed-storage sub-lot, a representative sample of 200 g was taken using a Boerner divider, and percentage seed damage determined. Pod-stored sub-lots were hand-shelled and sieved for adult pests. A representative seed sample was then taken, from which percentage seed damage was determined.

From the infestation and seed damage levels finally obtained, the initial levels (measured earlier) were subtracted. Thus the infestation/damage that occurred during storage was estimated.

Seed viability tests were thereafter conducted on 200 seeds.

Results and discussion. The results (Table 2) showed that pod storage was very effective in controlling C. *chinensis* infestation. It significantly reduced pest multiplication and seed damage. These reductions are most likely due to two reasons: the hairs on the pod hinder egg attachment, and the pod itself forms a barrier to both larval penetration and adult emergence (Silim-Nahdy and Odong 1994).

Table 2. *Callosobruchus chinensis* emergence and seed damage in pod-stored and seed-stored pigeonpea after 2 months of storage, Kawanda Agricultural Research Institute, Uganda, 1993/94.

Form of storage	Mean number of emerged adults	Mean seed damage (%)	Seed viability (%)
As seed	45 000	19.8	45.1
In pod	3.9	0.04	85.8

Traditional mud-straw-cowdung silo for C *chinensis* control

Pigeonpea seed is traditionally stored in a silo known as a *tua.* We constructed a *tua,* using the following materials: strands of grass locally known as *ochwici* or *lumbugu (Digitaria* sp), red clay soil from an ant-hill, and cowdung.

The grass strands were piled and covered with banana leaves for 3 days to allow the strands to soften. Clay soil was mixed with water to make a light mud paste. The grass strands were made into bundles (about 3 cm thick) and immersed in the soil mixture. The silo was then built by molding the straw bundles in a continuous circular motion to the desired shape and size.

The flat bottom was made first, then the wall, and finally a separate lid. The completed structure was smeared with mud and finally cowdung, and left to dry. The average volume of the silos was 100 L.

Treatments. Freshly harvested pigeonpea seed (variety Apio Elina, purchased from Lira) was used for the trial. The seed was first sorted, and all damaged seeds discarded. The clean seeds were bulk-disinfested by fumigation for 4 days under a fumigation sheet, using aluminum phosphide tablets @ 5 g V^1. Aeration was done for 24 h prior to the trials. Three treatments were used: storage in gunny bags, storage in a *tua* with a loosely placed cover, and storage in a *tua* with the cover sealed with clay-cowdung mixture. Forty kg of seed were used for each treatment, replicated four times.

Each container was infested with 24 pairs of 1-day old adult C. *chinensis.* The containers were stored for 3 months, after which seeds were sieved and insect numbers and seed damage determined. Seed damage was determined from a representative sample of 200 g. Seed viability tests were conducted on a 200 g seed sample from each treatment.

Results and discussion. The differences in infestation and seed damage between pigeonpea seeds stored in sacks, stored in a loosely covered *tua* and stored in a sealed *tua* were highly significant (P=0.005, Table 3). In gunny-sack storage, 75 727.7 insects and 17.6% seed damage was recorded. In contrast, the sealed *tua* had only 56.3 insects and 0.06% seed damage. Seed viability was also significantly lower in sack-stored seeds than in the sealed or loosely covered *tua.*

Table 3. *Callosobruchus chinensis* infestation and seed damage on pigeonpea stored for 3 months using different storage methods, Kawanda Agricultural Research Institute, Uganda, 1993/94.

Storage method	Mean number of adults emerged	Mean seed damage (%)	Seed viability (%)
Gunny sack	75 727(most alive)	17.6	35
Loosely covered *tua*	2512 (most dead)	3.81	74.3
Sealed *tua*	56.3 (all dead)	0.06	72.7

The results showed that the traditional method of pigeonpea storage in a sealed *tua* is an effective pest management option. Even the loosely covered *tua* was effective in controlling pest multiplication and seed damage. Sealing the containers may have resulted in a reduction in oxygen levels, possibly suffocating and killing the insects. Loosely sealed containers probably provided some degree of sealing, depending on the tightness of the lid and the smoothness of the contact surfaces.

Other options for C. *chinensis* management

Biorationals are a possible management option against C. *chinensis.* Several plant products were bioassayed for the control of C. *chinensis.* These include wood ash, lime peels, lemon peels, corn oil, burley tobacco, flue-cured tobacco, fire-cured tobacco, *Lantana camara* leaves, whole chillies, water hyacinth leaves, *Tephrosia* leaves, castor leaves, melia seed, lime grass, pineapple juice, banana juice, and pawpaw juice. Though most treatments seemed to reduce infestation, pest populations and seed damage remained significant. Tentative results have shown that the most promising of these plant products is *Tephrosia* leaves, followed by tobacco leaves.

Other methods being tested are seed splitting, and the use of lake sand. Varietal screening for resistance to C. *chinensis* in the field, in mature pods, and in seed has been initiated on 1200 varieties of pigeonpea.

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Pigeonpea Breeding Research in Tanzania

J K Mligo[1]

Introduction

Pigeonpea is an important grain legume in Tanzania. It ranks third among pulses (after beans and cowpea) in total production, and is the most important food legume in many of the low-altitude areas, especially in southern Tanzania. It is also widely grown in medium-altitude areas in the north, especially in Babati district. Pigeonpea is mainly intercropped with maize, sorghum, beans, and cowpea. Most farmers use tall, long-duration landraces that are susceptible to abiotic (terminal drought) and biotic (insect pests and diseases) stresses. The lack of improved cultivars is one reason for the low pigeonpea productivity in Tanzania. The breeding program is therefore geared towards identifying suitable varieties with acceptable qualities (bold- and white-seeded) in each maturity group.

Research in 1993/94

Research activities in the 1993/94 cropping season included varietal evaluations of short-, medium-, and long-duration genotypes for yield and other characters related to adaptation to different agroclimatic conditions; seed multiplication; and on-farm testing of promising varieties identified in previous trials. However, on-farm testing could not be conducted due to logistics problems. This paper briefly describes the work on varietal evaluation and seed multiplication.

Varietal evaluation

Results from five trials and an observation nursery are discussed below. These involved genotypes of different maturity durations, and were conducted at several locations in Tanzania.

EARCAL Short-duration Pigeonpea Regional Adaptation Trial

Eighteen short-duration genotypes received from the Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT, were tested at three locations—Ilonga,

1. Grain Legume Research Program, Ilonga Agricultural Research and Training Institute, P O Ilonga, Kilosa, Tanzania.

Kilombero Agricultural and Training Institute (KATRIN), and Mlingano—for yield and other characters. The trial was sown on 11 Mar at KATRIN, 31 Mar at Ilonga, and 19 Apr at Mlingano. These sowings were very late for the respective locations. At the time of writing, data from Mlingano had not been received.

At KATRIN insect pressure (especially pod borer) was very high. Rogor® 40 EC, the pesticide used, was not very effective, and grain yields were extremely low (0.06-0.4 t ha*[1]). Days to maturity ranged from 109 to 119. Trial results at Ilonga were good. Grain yields ranged from 0.94 to 2.23 t ha^{-1} with a location mean of 1.58 t ha^{-1} (Table 1). The two highest yielders, ICPL 86005 (2.23 t ha-[1]) and ICPL 90028 (1.92 t ha-[1]) were brown-seeded, a character unpopular with farmers. However, some white-seeded lines gave reasonably good yields, e.g., Kat 60/8 (1.77 t ha^{-1}), ICPL 87 W and ICPL 87091 (1.75 t ha^{-1}). The first two lines are already under seed multiplication for on-farm testing on the basis of earlier testing for several seasons. On average, the test lines matured within 104 days at this site.

Table 1. Performance of 18 genotypes in the EARCAL Short-duration Pigeonpea Regional Adaptation Trial, Ilonga, Tanzania, 1994.

	Days to		Plant height	Grain yield	100-seed	Seed
	Flowering	Maturity	(cm)	(t ha-[1])	mass (g)	color[1]
ICPL 86005	63	102	95.00	2.23	10.33	B
ICPL 90028	64	102	84.67	1.92	9.87	B
ICPL 87101	64	102	91.00	1.85	10.40	B
ICPL 87091	67	104	98.33	1.75	10.00	W
Kat 60/8	74	114	100.00	1.77	9.87	W
ICPL 87 W	66	105	86.33	1.75	8.87	W
ICPL 90024	63	102	92.00	1.65	8.70	B
ICPL 87109	66	104	100.33	1.63	9.67	W
ICPL 90029	65	104	84.33	1.56	12.57	B
ICPL 87115	66	104	106.00	1.56	7.17	B
ICPL 90001	61	104	82.66	1.56	8.20	B
ICPL 90050	63	102	98.67	1.54	7.40	B
ICPL 88027	66	104	87.67	1.50	7.60	W
ICPL 83024	64	104	82.33	1.54	10.23	B
ICPL 90013	66	103	86.33	1.21	8.10	W
ICPL 86012	63	102	81.67	1.42	10.53	W
ICPL 87105	65	104	90.00	1.12	8.40	W
ICPL 87104	64	103	77.00	0.94	10.47	B
Mean	65	104	90.24	1.58	9.32	
LSD (0.05)	2.72	1.61	0.95	0.71	9.55	
CV(%)	2.52	0.93	16.65	20.10	5.63	

1. W = white, B = brown

Regional Preliminary Short-duration Trial

This trial consisted of 12 short-duration lines developed at ICRISAT. The trial was conducted at two locations, Ilonga and KATRIN. As in the previous trial, insect pest pressure at KATRIN led to poor performances. Yields ranged from 0.34 to 1.06 t ha^{-1}, ICPL 90028 yielding the highest. The general performance of the test lines at Ilonga was good (location mean 1.57 t ha^{-1}). However, there were no significant differences among the test lines for grain yield (Table 2). The highest yields were recorded in two brown-seeded lines, ICPL 87101 (2.16 t ha^{-1}) and ICPL 87 (1.73 t ha-[1]). ICPL 86012 (1.59 t ha^{-1}), which was fifth in performance, is white-seeded and is already under seed multiplication for on-farm testing.

Medium-duration Pigeonpea International Trial

Previous varietal evaluations of medium-duration lines resulted in the identification of five promising lines (ICPL 87067, ICPL 87075, ICP 7035 W, Kat 50/8, and Kat 60/8), which are now under seed multiplication for on-farm testing. In this trial 13 new medium-duration lines developed at ICRISAT Asia Center, India, were evaluated at Ilonga with three replications. The location mean for grain yield was 1.67 t ha^{-1} (range 1.20-2.12 t ha^{-1}); no test line was superior to the controls. The highest yielders

Table 2. Performance of 12 genotypes in the Regional Preliminary Short-duration Pigeonpea Trial, Ilonga, Tanzania, 1994.

	Days; to					
Genotype	Flowering	Maturity	Plant height (cm)	Grain yield (t ha^{-1})	100-seed mass (g)	Seed color[1]
ICPL 87101	64	112	112.7	2.16	13.2	B
ICPL 87	63	108	99.3	1.73	10.2	B
ICPL 90028	63	110	97.0	1.67	14.9	B
ICPL 86005	62	112	113.7	1.62	11.2	B
ICPL 86012	61	108	102.0	1.59	12.4	W
ICPL 90029	64	111	107.0	1.54	14.1	B
ICPL 83024	62	112	104.0	1.51	15.1	B
ICPL 87105	64	111	105.7	1.47	11.3	W
ICPL 88027	65	109	100.3	1.47	9.9	W
ICPL 87104	62	108	102.3	1.44	12.2	W
ICPL 88023	63	113	97.7	1.37	11.9	B
ICPL 90024	62	111	99.3	1.32	10.0	W
Mean	63	110	103.4	1.57	12.2	
LSD (0.05)	2.5	3.6	9.6	ns	0.8	
CV(%)	1.74	1.4	5.5	19.78	4.0	

1. W = white, B = brown
ns = not significant

were the brown-seeded control ICPL 87119 (2.12 t ha^{-1}) and a white-seeded line, ICPL 93002 (2.10 t ha^{-1}). Most of the lines matured within 140 days, with a very narrow range of 138-144 days. Seed mass ranged from 10.0 to 12.0 g 100 $seed^{*1}$ (mean 11.27).

Regional Preliminary Long-duration Trial

This trial, consisting of 12 white-seeded, long-duration lines from the Regional Pigeonpea Project, Malawi, was sown at Ilonga on 8 Feb and at Mlingano on 19 Apr with three replications. The trial at Mlingano had just started podding at the time of writing. At Ilonga the grain yield location mean was 0.88 t ha^{-1} (range 0.55-1.05 t ha^{-1}) with the highest yield (1.05 t ha^{-1}) from QP 38. Maturity duration ranged from 165 to 177 days and 100-seed mass from 11.0 to 14.3 g. Some of the lines tested in this trial yielded as much as 4 t ha^{-1} in the previous season (1992/93) at Ilonga when sown in Jan (Mligo and Myaka 1994). The reduced yields in 1993/94 could be explained only partly by the difference in sowing date. The lines therefore need further testing.

Preliminary Long-duration Trial

This trial, formulated by the Tanzanian national program consisted of 17 lines that had earlier performed well in preliminary and nursery observation trials at Ilonga in 1992/93 (one replication, Jan sowing). In 1993/94 the trial was sown at four locations (Ilonga, Ismani, Hombolo, and Naliendele) with four replications. Sowing at Ismani (a semi-arid location) was delayed by late onset of rains, and the trial was sown only in early Feb. The rains ended earlier than normal; the trial therefore suffered from terminal drought and no yield data were recorded from this site. At Hombolo too, terminal drought affected the trial, and yields were too low (location mean 0.16 t ha^{-1}) for any meaningful comparisons. The Ilongo trial was sown in a fusarium wilt sick plot. Results on fusarium incidence are reported elsewhere in these Proceedings. The highest yield at Ilonga was from the wilt-resistant line ICPL 9145 (1.75 t ha^{-1}). The performance of the test lines at Naliendele was unimpressive (location mean 0.87 t ha^{-1}). The problems at this site were poor soils and insect pests, especially the pod borer. Since the 1993/94 results are not conclusive, the trial needs to be repeated.

Regional Preliminary Observation Nursery

This trial, consisting of 12 long-duration germplasm lines from the Pigeonpea Project, Malawi, was sown at Ilonga with one replication and at Naliendele with two replications. As in the long-duration trial, performances at Naliendele were poor: grain yields were very low (location mean 0.54 t ha^{-1}); maturity duration ranged from 170 to 180 days, and 100-seed mass from 10.5 to 15.5 g.

The test lines performed well at Ilonga (location mean 1.2 t ha^{-1}, Table 3). The two highest yielders were white-seeded lines 9246-1 (1.72 t ha^{-1}) and 9254-1 (1.67 t ha^{-1}). Lines 9247-3 and 9244-25 appeared to be highly susceptible to fusarium wilt, and failed to yield. The trial needs to be repeated in diverse environments, with more replications.

Seed multiplication

Three of the seven pigeonpea lines earmarked for on-farm evaluation were multiplied during the 1993/94 cropping season: ICPL 86012 (27 kg), ICPL 87075 (19 kg), and Kat 50/8 (28 kg). The other four lines (ICPL 87 W, ICP 7035 W, Kat 60/8, and ICPL 87067) will be multiplied during the 1994 dry season.

Table 3. Performance of 20 genotypes in the Regional Preliminary Pigeonpea Observation Nursery, Ilonga, Tanzania, 1994.

Genotype	Days to Flowering	Days to Maturity	Plant height (cm)	Grain yield (t ha^{-1})	100-seed mass (g)	Fusarium wilt score[1]	Seed color[2]
9246-1	112	156	181	1.72	12.6	L	W
9254-1	106	162	252	1.67	12.7	L	W
9252-1	114	162	232	1.55	12.6	L	W
9246-3	104	159	222	1.53	8.8	L	W
9232-1	110	162	254	1.39	11.1	M	W
HY 3C-2	110	159	236	1.28	11.3	L	W
9251-1	106	159	241	1.25	12.7	L	W
9247-24	100	156	117	1.25	14.3	L	B
9246-12	106	154	223	1.25	12.0	S	W
Sample 6-3	114	162	219	1.17	11.9	S	W
Luwe 1-5	106	159	220	1.14	10.7	s	W
9247-1	106	159	205	1.11	11.6	s	W
HY 3C-1	110	162	215	1.11	11.1	L	W
9246-22	104	159	198	1.05	12.2	L	W
9202-1	110	162	274	1.05	12.1	M	W
9253-4	104	159	215	0.83	11.1	M	W
9246-11	106	156	215	0.75	11.2	L	W
8002-3	110	159	238	0.55	12.7	S	W
9247-3	110	F[3]	F	F	F	S	B
9244-25	106	F	F	F	F	s	W
Mean	107	159	220	1.20	11.8		

1. S = severe, M = medium, L = low
2. W = white, B = brown
3. F = no yield due to fusarium wilt

Future research plans

On-farm testing. Promising short- and medium-duration lines will be tested on farmers' fields to evaluate on-farm performance and to elicit farmers' perceptions of the varieties being tested (with reference to plant type, yield, seed color, and seed size).

Seed multiplication. Lack of seed is a major constraint to the spread of released cultivars. The aim of this work is to multiply seed of the most promising cultivars and make it available to farmers.

Back-up research. Varietal trials involving recently developed short-, medium-, and long-duration pigeonpea lines will continue, with the objective of identifying superior lines for on-farm testing and subsequent release. Screening pigeonpea germplasm for fusarium wilt resistance on the new wilt sick plot will be intensified.

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Fusarium Wilt Screening in Tanzania

A M Mbwaga[1]

Introduction

More than 50 crop pathogens have been reported to affect pigeonpea (Nene 1980). In Tanzania, the pigeonpea diseases of economic importance include fusarium wilt, leaf spot, powdery mildew, *Macrophomina* stem canker, and rust (Kannaiyan et al. 1984). In surveys conducted in Kilosa district during the 1988 cropping season, it was observed that fusarium wilt was a major constraint, with wilt incidence ranging from 10% to 96% on farmers' fields (Mbwaga 1988). As a result of this survey a screening program for fusarium wilt resistance was initiated at the Ilonga Research Station, using short- and medium-duration lines from ICRISAT Asia Center, India.

Short-duration lines

Six short-duration pigeonpea lines from ICRISAT (ICPLs 87, 83024, 85012, 85014, 86005, and 86012) were evaluated in 1989/90 and 1990/91 for fusarium wilt resistance at a disease hot spot in farmers' fields in Kilosa district. All six lines were susceptible, with mean wilt incidence for the two seasons ranging from 54.7 to 79.5%. Screening of short-duration lines was then discontinued in view of the high degree of susceptibility, and also because farmers in Tanzania prefer medium-duration varieties to short-duration ones.

Medium-duration lines

Nine medium-duration lines were evaluated at the same disease hot spot, five of them for 3 years (1989/90 to 1991/92). Two lines (ICPL 270 and ICPL138) were found to be relatively resistant to fusarium wilt (Table 1). Though they showed wilt incidence of 31.8 and 38.9%, these lines represented the highest level of resistance then available in Tanzania.

Long-duration lines

The 16 entries in this trial were evaluated for yield in an observation trial in the 1992/93 season, and found very promising. In 1993/94, the trial was sown in a wilt

1. Ilonga Agricultural Research and Training Institute, P O Ilonga, Kilosa, Tanzania.

Table 1. Fusarium wilt incidence in nine medium-duration pigeonpea lines tested in Kilosa district Tanzania.

Genotype	Fusarium wilt incidence (%) 1989/90	1990/91	1991/92	Mean
ICPL 270	22.0	34.7	38.8	31.8
ICPL138		20.5	57.3	38.9
ICPL 8863	15.3	54.3	51.9	40.5
ICP 7035		51.2	31.9	41.6
ICPL 304	54.2	49.1	39.0	47.4
ICPL 332	50.8	56.4	44.5	50.6
ICPL 131	39.3	80.9	40.8	53.7
Kat 60/8			52.0	52.0
Kat 50/3			58.6	58.6
Mean	36.3	49.6	46.1	
SD±	17.2	18.8	9.3	

Table 2. Fusarium wilt incidence in the Long-duration Preliminary Yield Evaluation Trial, Ilonga, Tanzania, 1993/94.

Genotype	Fusarium wilt incidence (%)
ICP 9145	9.8
PGM 9233	12.3
PGM 9234	15.2
HY3E	19.0
PGM 9208	19.2
QP37	29.2
QP15	47.2
PGM 9229	49.1
PGM 9226	51.2
QP14	51.3
Royes	55.6
PGM 9215	61.5
PGM 9227	69.9
QP38	71.7
PGM 9232	75.0
PGM 9201	82.6
Local control	38.7
Mean	44.6
SD	±23.7

sick plot at Ilonga. ICP 9145 had the lowest incidence (9.8%), followed by PGM 9233, PGM 9234, and HY 3E (Table 2). The trial will be repeated at the same site in the 1994/95 season to confirm these preliminary results.

ICP 9145 was identified at ICRISAT Asia Center as being resistant to fusarium wilt, and has been released in Malawi as a wilt-resistant variety. This line has a high potential for adoption in the Mtwara and Lindi regions in southern Tanzania, which are at the same latitude as the main pigeonpea areas in Malawi. Mtwara and Lindi are major pigeonpea areas, but production is affected by high incidence of fusarium wilt.

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Pigeonpea Agronomy Research in Tanzania: Recent Results and Future Plans

F A Myaka[1]

Introduction

Pigeonpea *(Cajanus cajan)* is an important grain legume in Tanzania. The main production areas are the Lindi and Mtwara regions in the south and Babati district in the north. Pigeonpea is also important along the coast and in the Morogoro region, where it is used mainly as a vegetable (green peas). This paper discusses the progress and recent results of on-station agronomy research in Tanzania on pigeonpea sowing date, plant spacing, and intercropping. Plans for future research are also discussed.

Short-duration pigeonpea plant spacing

Plant spacing is a key management practice for the optimal production of any crop. Optimal spacing would depend on climate, soil conditions, rainfall pattern, and the cropping system. Research at ICRISAT Asia Center has shown that improved short-duration pigeonpea genotypes give optimal yield at close spacing (30 x 10 cm) (ICRISAT 1985). However, our experience in Tanzania has shown that very closely spaced rows are difficult to weed, especially when a hand hoe is used. Perhaps for this reason, very small interrow and within-row spacings are unacceptable to farmers.

An experiment was therefore initiated in the 1992/93 season (Mligo and Myaka 1994) to determine the extent to which interrow and within-row spacing could be increased without a significant reduction in yield. In the 1993/94 season the experiment was conducted at two locations, using a randomized complete block design with three replications. ICPL 86005 was sown at three levels of interrow spacing (40, 50, and 60 cm), two levels of within-row spacing (20 and 30 cm), and two levels of plants per hill (1 and 2). The trial was sown at Hombolo on 7 Feb and Ilonga on 12 Feb 1994. Ilonga is classified as a wet to moderately wet environment and Hombolo as a dry environment.

At Ilonga, interrow spacing had no significant effect ($P>0.05$) on grain yield. The previous season's results had indicated that it was possible to increase spacing in a wet environment without significantly reducing yield. However, this season's results show that yield would also depend on within-row spacing. More widely spaced rows seem to give higher yields at closer within-row spacings, while closely spaced rows yield better at wider within-row spacings (Table 1, $P<0.05$). At Hombolo, in contrast to Ilonga, interrow spacing did have a significant effect ($P<0.05$) on grain yield, and

1. Ilonga Agricultural Research and Training Institute, P O Ilonga, Kilosa, Tanzania.

closely spaced rows yielded better than widely spaced ones. As in the previous season, within-row spacing and number of plants per hill had no significant effect on grain yield (Table 1).

It is evident from the two seasons' results that optimum spacing is different for each environment (Mligo and Myaka 1994).

Short-duration pigeonpea sowing date

It is thought that if the sowing of short-duration pigeonpea is delayed such that low temperatures prevail during part of the reproductive phase, some key pests might be reduced to below economic threshold levels. An experiment was therefore initiated in 1992/93 (Mligo and Myaka 1994) to test this hypothesis under Tanzanian conditions. In 1993/94, the experiment was conducted at Ilonga and Gairo. The Gairo trial failed due to poor plant establishment; results from Ilonga are reported here.

ICPL 86005 was sown at three different dates at Ilonga under sprayed and non-sprayed conditions. A randomized complete block design with three replications was used, with treatments arranged factorially. Sowing dates were 3 Feb, 5 Mar, 18 Mar, and 11 Apr 1994.

The results showed a significant effect of sowing date on yield and yield components (Fig. 1). There was significant ($P<0.05$) yield reduction on pigeonpea sown after 5 Mar, probably due to reduced yield components (Fig. 1). Insecticide application

Table 1. Effect of plant spacing and number of plants $hill^{-1}$ on grain yield of short-duration pigeonpea at Ilonga and Hombolo, Tanzania, 1994.

	Grain yield ($t\ ha^{-1}$) at different within-row spacings		
Interrow spacing	20 cm	30 cm	Mean
Ilonga			
40 cm	1.11	2.09	1.60
50 cm	1.57	1.34	1.45
60 cm	2.00	1.37	1.69
Mean	1.56	1.60	
SE (interrow x within-row) ± 0.154 ($P<0.05$)			
All remaining effects nonsignificant ($P>0.05$)			
Hombolo			
40 cm	0.77	0.74	0.75
50 cm	0.62	0.85	0.74
60 cm	0.57	0.55	0.56
Mean	0.65	0.71	
SE (interrow spacing) ±0.062 ($P<0.05$)			
All remaining effects nonsignificant (>P0.05)			

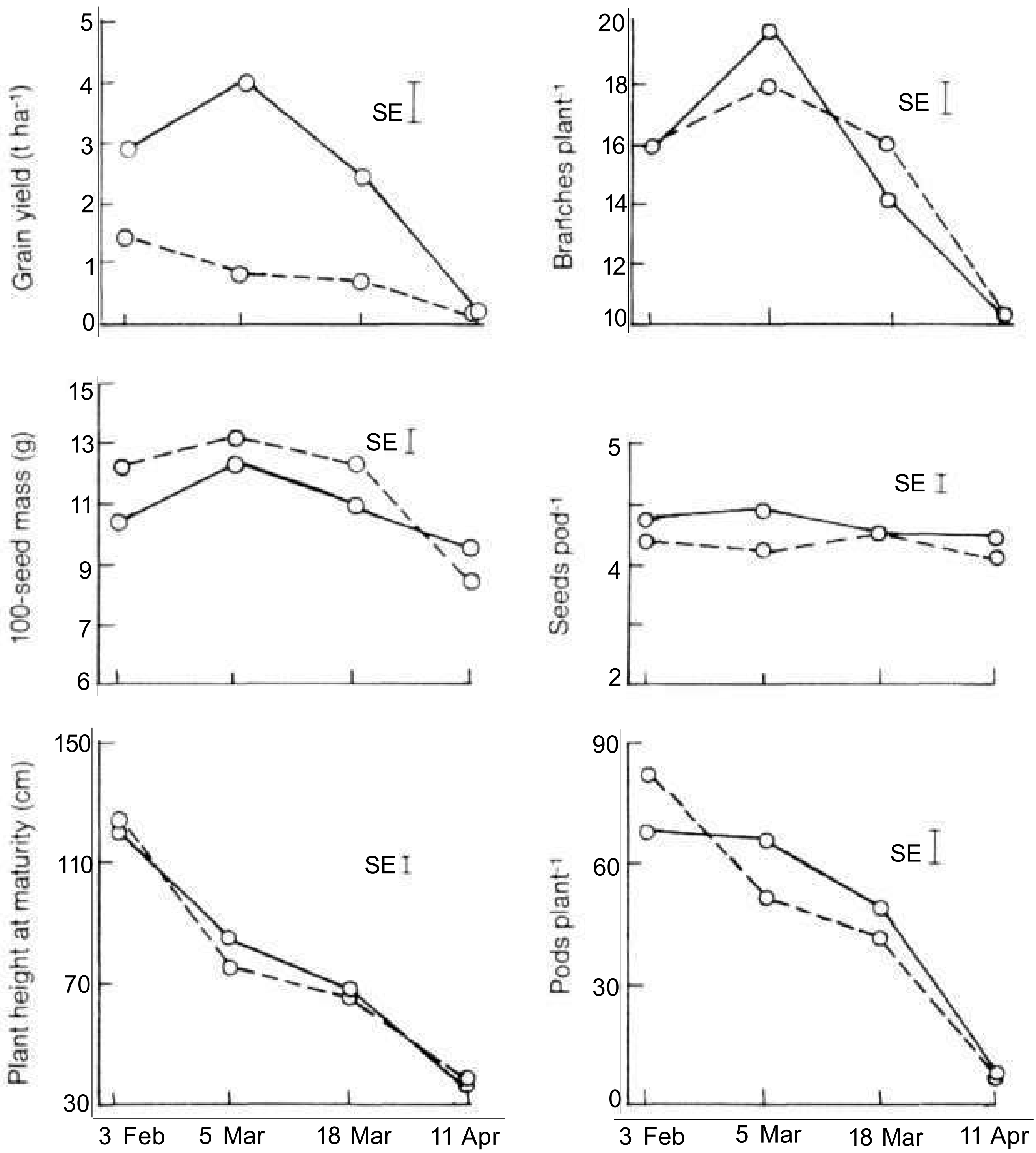

Figure 1. Effect of sowing date and insecticide application on yield and yield components of short-duration pigeonpea, Ilonga, Tanzania, 1994.

sprayed unsprayed

significantly ($P<0.05$) affected grain yield, but not the yield components ($P>0.05$) (Fig. 1). Low temperatures during part of the reproductive phase probably affected the activity of pod borers, but not of pod-sucking insects. This is evidenced by reduced pod borer damage and increased damage by pod-sucking insects during this period (Fig. 2).

It seems that low temperatures at Ilonga (Fig. 2) coincide with the period of high moisture deficit due to terminal drought. Year to year variations in onset and distribution of rainfall further complicate the situation. It is possible that reduced pest incidence during this period at this location might not lead to better yields unless supplemental irrigation is provided. Such irrigation is generally not available, but pigeonpea crops grown in valley bottoms (using post-rice residual moisture) would be likely to benefit.

Maize/pigeonpea intercropping

Pigeonpea is intercropped with maize in Babati, a major pigeonpea production area. Farmers in the area use long-duration cultivars that often suffer from terminal drought stress. The available promising improved medium-duration genotypes, which had been tested under sole crop conditions, were evaluated at Babati as a maize intercrop. Two improved genotypes (Kat 60/8 and ICPL 87075) and a local landrace were intercropped with maize or grown as sole crops at high (55 500 plants ha^{-1}) and low (27 700 plants ha^{1}) densities under sprayed and nonsprayed conditions. Farmers were impressed with both genotypes because they matured earlier than the local landrace. At the time of writing, the local landrace was not ready for harvest; results of this trial could therefore not be reported.

Sorghum/pigeonpea intercropping

On the basis of data for three seasons (1991-93), short-duration pigeonpea is likely to perform better than short-duration sorghum in dry environments, while the reverse is true in wet environments. Pigeonpea yield increased with an increase in row ratio. Land use efficiency of this intercrop varied between seasons, but the mean values over seasons showed that a 1:1 and 1:2 sorghum:pigeonpea row ratio was more efficient than sole sorghum/pigeonpea or the other intercropping ratios tested.

Future research

On-farm testing. After several seasons of on-station research, some of the experiments (e.g., intercropping short-duration pigeonpea with maize/sorghum) have been concluded. The recommendations made on the basis of these trials will be tested on farmers' fields simultaneously with varietal evaluations. ICPL 87091 has been identified as having the qualities most preferred by Tanzanian farmers. This genotype, and

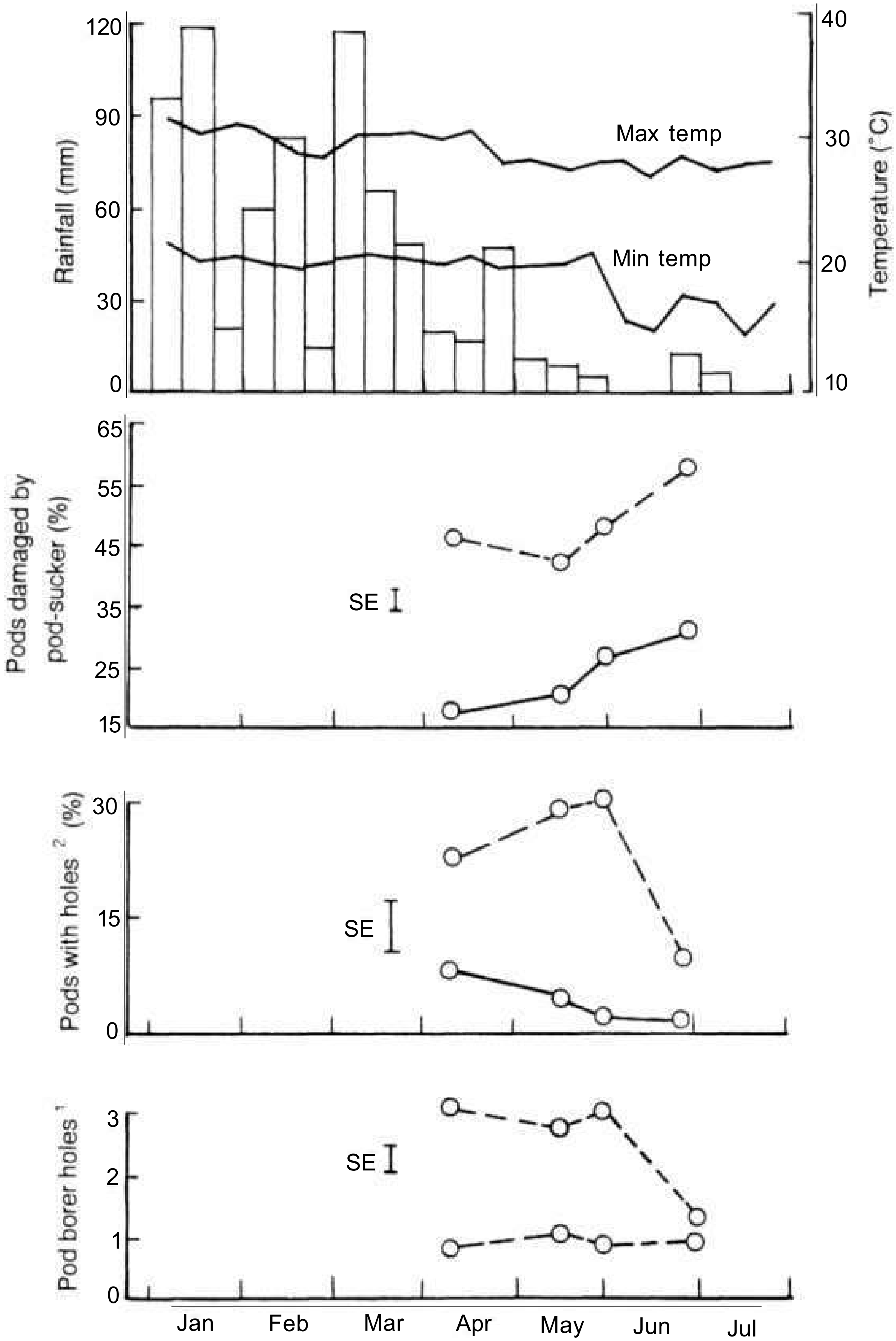

Figure 2. Relationships between insect damage, weather parameters, sowing date, and insecticide application in short-duration pigeonpea, Ilonga, Tanzania, 1994.

1. Square root transformed values. 2. Arcsine transformed values.

other promising ones, will be tested as sole crops and as cereal intercrops (see Tanzania workplan elsewhere in this publication).

Back-up research. On-station work on short-duration pigeonpea will continue, with more specific targeting at solving farmers' problems. The trial on new cropping systems for short-duration pigeonpea will be sown at Ilonga and Mlingano. Mlingano is a location with reliable short rains. The sowing date experiment on short-duration genotypes will continue for another season, with the next sowing during the short rains in 1995. The number of treatments in the short-duration spacing experiment will be reduced in view of the results obtained in 1992/93 and 1993/94. At Ilonga, closer spacing treatments will be dropped while at Hombolo very wide spacings will be dropped (see Tanzania workplan).

Survey of production systems. The survey will be carried out in the two major pigeonpea production areas to assemble a database for research evaluation and impact assessment (see Tanzania workplan).

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Pigeonpea Research for Rainfed Production Systems in Western Sudan

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Introduction

The sandy soils of western Sudan are very poor in fertility and susceptible to wind and water erosion. The introduction of inorganic fertilizers is not economically feasible, and rainfall is insufficient to fully activate the fertilizers. It is therefore necessary to introduce drought-tolerant legumes to improve soil conditions. Cropping systems with legume components will ensure sustainable agricultural production. Pigeonpea could become a successful crop in the Sudan. Besides improving fertility and physical soil properties, it can provide food and feed. Research efforts are continuing, with the objective of identifying promising cultivars with high and stable yields, and optimum cropping systems where these cultivars will fit, to stimulate pigeonpea production in western Sudan.

This paper reports the results of investigations in the rainfed millet-based cropping systems in North Kordofan. The main focus was on varietal testing and cropping systems research. Our efforts were catalyzed and encouraged by the ICRISAT/EARCAL (Eastern Africa Regional Cereals and Legumes) Program in Kenya.

Rainfall during the 1993/94 season was 358 mm, fairly well distributed over the season.

Varietal evaluation trials

Five trials were conducted in 1993/94:

- EARCAL Observation Nursery
- Preliminary Varietal Trials (two trials)
- Extra Short Duration Varietal Trial
- Short-duration Varietal Yield Trial

EARCAL Observation Nursery

Materials and methods. Eleven varieties received from EARCAL, Kenya, were evaluated in a non-replicated trial with a local control. The nursery was sown on 28 Jul and harvested on 17 Dec 1993, 13 Jan, and 10 Feb 1994. Spacing was 75 x 30 cm.

1. El-Obeid Research Station, P O Box 429, El-Obeid, Sudan.

Plants were thinned to two plants hole-^{1} 18 days after sowing, giving a theoretical plant population of 89 000 plants ha-^{1}. Plot size was 4 rows of 5 m length. The two central rows were harvested to estimate seed and pod yields. Plant stand at harvest, days to flowering, and plant height were also measured.

Results and discussion. Results are presented in Table 1. There was no loss of stand between thinning and harvest. The trial mean yield was 0.42 t ha^{-1}. The highest yields were obtained from ICPL 87 W (0.70 t ha-^{1} seed, 0.92 t ha-^{1} pods) and ICPL 87 B (0.65 t ha-^{1} seed, 0.79 t ha-^{1} pods). The mean time to flowering was 80 days. The earliest cultivar to flower was ICPL 83020 (65 days), and the last was the local variety (104 days). Plant heights ranged between 58 and 100 cm (mean 68 cm).

Pigeonpea Preliminary Varietal Trial I

Materials and methods. Four varieties received from ICRISAT/EARCAL were evaluated with a local control. A randomized block design was used with four replications. Plot size was 4 rows of 4 m length, with 75 x 30 cm spacing. Plants were thinned to two plants hole-^{1} 2 weeks after sowing. The trial was sown on 21 Jul 93 and harvested four times; on 2 Dec, 29 Dec 1993, 23 Jan, and 10 Feb 1994.

Table 1. Performance of 12 pigeonpea tines (EARCAL nursery) at El-Obeid Research Station, Sudan, 1993/94.

Genotype	Yield[1] (t ha^{-1}) Seed	Pod	Stand at harvest (plants m-2)	Days to 50% flowering	Plant height (cm)
ICPL 87 W	0.70	0.92	8	70	62
ICPL 87 B	0.65	0.79	8	68	60
ICPL 151	0.53	0.74	8	69	65
ICPL 1104	0.49	0.61	7	69	63
ICPL 83020	0.48	0.64	8	65	66
ICPL 88027	0.45	0.62	9	73	68
Kat 60/8	0.34	0.53	8	91	72
Kat 66	0.32	0.48	8	88	70
Local	0.31	0.51	8	104	100
ICPL 3869	0.31	0.42	8	100	58
Kat 50/3	0.22	0.33	8	85	75
ICPL 88023	0.16	0.20	8	78	57
Mean	0.42	0.56	8	80	68
SE±	0.048	0.058	0.12	3.8	3.3

1. Total yield from all harvests

Table 2. Performances in Pigeonpea Preliminary Varietal Trial 1 (ICRISAT/EARCAL), El-Obeid Research Station, Sudan, 1993/94.

Genotype	Yield[1] (t ha^{-1}) Seed	Yield[1] (t ha^{-1}) Pod	Plant stand (m^{-2}) After thinning	Plant stand (m^{-2}) At harvest	Days to First flower	Days to 50% flowering	Branches plant^{-1}	Plant height (cm)
ICPL 3869	0.95	1.38	8	7	62	85	7	74
ICPL 87	0.84	1.24	6	5	56	69	6	48
Local	0.67	0.91	8	7	85	100	8	98
Kat 878	0.60	0.89	8	7	82	99	7	114
ICPL 87104	0.57	0.83	6	6	53	72	5	64
Mean	0.73	1.05	7	6	68	85	6	79
SE±	0.087*	0.118*	0.47*	0.42*	0.84***	1.66***	0.34***	2.05***
CV(%)	24	22	13	13	2.5	3.9	11	5

* significant at 5%, ** significant at 1%, *** highly significant
1. Total yield from all harvests

Results and discussion. Results are presented in Table 2. The varieties were significantly different in seed yield, pod yield, days to flowering, and plant height. In contrast to the earlier trial, mean population densities after thinning and at harvest were significantly different.

The trial mean yields were 0.73 t ha^{-1} (seed) and 1.05 t ha^{-1} (pod). The highest yielders were ICPL 3869 (0.95 t ha^{-1} seed, 1.38 t ha^{-1} pod) and ICPL 87 (0.84 t ha^{-1} seed, 1.24 t ha^{-1} pod). The local variety gave 0.67 t ha^{-1} (seed) and 0.91 t ha^{-1} (pod). Days to 50% flowering varied from 69 (in ICPL 87) to 100 (local variety), with a mean of 85 days. Plant heights ranged from 48 to 114 cm.

Pigeonpea Preliminary Varietal Trial II

Materials and methods. Nine varieties received from ICRISAT Asia Center, India, during the period 1987-93, were evaluated with a local control in a randomized block design with four replications. Plot size was six rows of 7 m length, with a spacing of 75 x 25 cm. Plants were thinned to one plant hole^{-1}, giving a theoretical population of 53 000 plants ha^{-1}. The trial was sown on 22 Jul and harvested twice, on 28 Nov 1993 and 5 Jan 1994. The four central rows were harvested to estimate seed, pod, and stalk yields.

Results and discussion. Seed and pod yields were very low. The theoretical population density (53 000 plants ha^{-1}) was much lower than in the other trials; and this was further reduced to 30 000 ha*^{1} at harvest. This could partially explain the low seed and pod yields obtained.

The varieties were not significantly different in seed, pod, or stalk yields. However, there were significant differences in flowering period and 100-seed mass (P=0.001).

The results (means) were as follows: 87 days to 50% flowering, 129 days to 95% maturity, 100-seed mass 9.5 g, plant height 70 cm, seed yield 0.09 t ha^{-1}, pod yield 0.14 t ha^{-1}, and stalk yield 0.38 t ha^{-1}. Variety WB 20 (205) produced the highest seed yield (0.14 t ha^{-1}, as against 0.06 t ha^{-1} for the local landrace). The largest seed size (10.0 g 100 $seed^{-1}$) was recorded in ICPL 312, which was also the earliest to mature.

Extra Short Duration Pigeonpea Varietal Trial

Materials and methods. Two experiments comprising 38 extra short duration pigeonpea lines received from ICRISAT Asia Center, were evaluated. Experiment 1 consisted of 20 determinate lines and Experiment 2 of 18 indeterminate lines. Both experiments were arranged in a randomized complete block design with three replications. Sowing dates were 17 Jul (Experiment 1) and 18 Jul (Experiment 2). Plot size was four rows of 5 m length, with a spacing of 60 x 30 cm. Plants were thinned to one plant $hole^{-1}$ 15 days after emergence. Plants were harvested twice in both experiments; 103 and 117 days after sowing in Experiment 1 and 105 and 119 days after sowing in Experiment 2.

Results and discussion. Results from Experiment 1 (determinate lines) are shown in Table 3. ICPL 89027 gave the highest grain yield (0.43 t ha^{-1}), followed by ICPL 89020 (0.32 t ha^{-1}) and ICPL 88009 (0.30 t ha^{-1}). ICPL 89027 and ICPL 88009 recorded the highest 100-seed mass and also among the best dry matter yields.

In contrast to the determinate lines, differences between the indeterminate lines (Experiment 2) were not significant for any of the parameters measured. Seed yields were much lower than in the determinate lines, ranging between 0.07 and 0.22 t ha^{-1}; ICPL 90039 was the highest yielder. Plant heights ranged from 48 to 71 cm, and 100-seed mass from 6 to 8 g. Hence, a multilocational yield trial of 12 entries will be constituted solely from the determinate lines for further evaluation.

Pigeonpea Short-duration Varietal Yield Trial

Materials and methods. Eight varieties received from ICRISAT/EARCAL were evaluated for yield along with a local control, at four locations (El-Obeid, El-Nuhud, Sunjukaya, and Angar Ko). Due to either poor establishment or severe insect attack at the pod stage, the latter three locations provided no proper data. Yield data were collected only from one location, El-Obeid Research Farm.

The nine varieties were sown in mid Jul 1993 in a randomized block design with four replications. Plot size was four rows of 5 m length, with a spacing of 60 x 30 cm. Plants were thinned to one plant $hole^{-1}$.

Results and discussion. Differences in seed yield among varieties were not significant (P=0.05), but all varieties except Kat 60/8 outyielded the local variety. The best

Table 3. Performances in the Extra Short Duration Pigeonpea Varietal Trial (Determinate), El-Obeid Research Station, Sudan, 1993/94.

Genotype	Grain yield[1] (tha-1)	Stand at harvest ('000 plants ha-1)	Dry matter yield[1] (tha-1)	Plant height (cm)	Days to 50% flowering	100-seed mass (g)
ICPL 89027	0.43	75	0.12	50	54	10
ICPL 89020	0.32	33	0.69	57	57	9
ICPL 88009	0.30	47	0.86	81	63	10
ICPL 88017	0.28	44	0.10	57	59	8
ICPL 88007	0.27	32	0.64	67	56	9
ICPL 93015	0.26	43	0.72	50	58	8
ICPL 90011	0.24	55	0.79	47	58	9
ICPL 4	0.23	40	0.67	55	59	6
ICPL 90008	0.22	31	0.59	48	57	8
ICPL 90005	0.20	43	0.66	42	54	10
ICPL 88015	0.20	47	0.65	51	56	8
ICPL 88001	0.19	47	0.56	46	63	9
ICPL 89095	0.19	35	0.49	42	54	8
ICPL 90001	0.18	46	0.72	57	57	10
ICPL 94023	0.16	28	0.36	49	61	8
ICPL 90012	0.15	27	0.40	42	64	9
ICPL 90004	0.14	36	0.47	52	60	9
ICPL 95010	0.13	36	0.43	44	56	8
ICPL 89024	0.11	15	0.26	33	57	8
ICPL 88003	0.11	33	0.31	44	57	7
SE±	0.050**	9*	0.15"	8	3	r
CV(%)	40	39	42	26	8	15

* significant at 5%, ** significant at 1%

1. Total yield from both harvests

yield (0.17 t ha^{-1}) was obtained from ICPL 151 and the poorest yield (0.05 t ha^{-1}) from Kat 60/8. The local variety gave a yield of 0.12 t ha^{-1}.

Pigeonpea in different cropping systems

Materials and methods. Pigeonpea performance in different intercropping systems was compared during the 1993/94 season at El-Obeid Research Farm. Pigeonpea represented the minor crop, and one of millet, groundnut, sesame, or cowpea was the major crop. The treatments were arranged in a randomized block design with four replications. Twelve rows of each intercrop (3:1 ratio of major:minor crop rows) and six rows of each sole crop were sown, each 5 m long. Interrow spacing was 60 cm,

Table 4. Pigeonpea performance in different intercropping systems, El-Obeid Research Station, Sudan, 1993/94.

Cropping system	Row arrangement	Yield ($t\ ha^{-1}$) Main crop	Pigeon-pea	Main crop as a fraction of sole	Pigeonpea as a fraction of sole	LER[1]
Millet/ pigeonpea	3:1	0	0.11	0	0.38	0.4
pigeonpea	3:1	0.89	0.05	0.82	0.17	1.0
Sesame/ pigeonpea	3:1	0.08	0.15	0.53	0.52	1.1
Cowpea/ pigeonpea	3:1	0.45	0.07	0.50	0.24	0.7
Sole millet		0				1.0
Sole groundnut		1.09				1.0
Sole sesame		0.15				1.0
Sole cowpea		0.90				1.0
Sole pigeonpea			0.29			1.0

1. Land equivalent ratio

while within-row spacings were 50 cm for millet, 40 cm for pigeonpea, and 20 cm for sesame and groundnut. The varieties used were Hereihree for millet, Hereihree for sesame, Sodiri for groundnut, Ain El-Gazal for cowpea, and the local pigeonpea. The seeds were treated with Furnisan® before sowing @ 3-5 g kg^{-1}. Sowing was done in mid Jul, and harvesting in Nov and Dec 1993.

Results and discussion. Results are presented in Table 4. The millet crop failed totally, and no yields were obtained. Pigeonpea yields were very low, probably due to the fact that we used the local variety, which is late-maturing and susceptible to drought. In future trials, short-duration varieties from ICRISAT will be used. Yields of sesame were also low due to heavy infestation by the sesame web worm *(Antigastra* sp). However, the land equivalent ratio (LER) in the sesame/pigeonpea intercrop (1.1) was the highest among the various intercrops.

Studies on Short-duration Pigeonpea Varieties under Irrigation in the Sudan

M A M Khair[1]

Introduction

Pigeonpea in the Sudan is grown mostly on the banks of irrigation canals in the irrigated schemes. A few farmers grow pigeonpea as a major field crop in the New Haifa Scheme, an irrigated area in eastern Sudan. A 5-component rotation (fallow-cotton -wheat-groundnut+sorghum -forage legume) was introduced recently in the Gezira scheme, with 168 000 ha earmarked for forage legumes. However, farmers are reluctant to sow forage legumes during the recommended period (Jun), preferring instead to sow them in Mar, when water is not available. In Jun, when water (and hence pastures) are available, they prefer to grow not forage crops but sorghum and groundnut.

Pigeonpea can play a major role in the areas planned for forage legumes, providing grain, stalks for firewood, and hay for livestock. Moreover, it is a drought-tolerant crop. The local variety is a medium-duration type, and short-duration varieties would be more appropriate. The current study deals with the evaluation of several short-duration varieties.

Materials and methods

This is the first season for this experiment, in which 12 short-duration genotypes received from ICRISAT/EARCAL, Kenya, were evaluated. The genotypes were: Kat 60/8 and ICPLs 87 B, 87 W, 151, 83016, 86005, 87091, 87101, 87102, 87104, 90028, and 90029. The experiment was sown on 12 Aug 1993 in the heavy cracking clays of the Gezira Research Farm, Wad Medani, Sudan. Rainfall distribution at Wad Medani during the experiment is shown in Table 1.

The experiment was sown on ridges 80 cm apart, in double rows (one on either side of the ridge), with one seed per hole. Within-row spacing was 15 cm. Due to a shortage of seed each plot consisted of three 2.5-m long ridges. A randomized complete block design was used with three replications. One replication suffered from severe waterlogging; data are presented from two replications only. Weeding was performed manually as needed. In addition to the rainfall, five irrigations were applied at monthly intervals. The observations included seed yield, 100-seed mass, plant height, and days to flowering and maturity.

1. Agricultural Research Corporation, Gezira Research Station, P O Box 126, Wad Medani, Sudan.

Table 1. Rainfall distribution in Wad Medani, Sudan, during the experimental period, 1993.

Month	Rainfall (mm)'
Jun	23.4
Jul	9.2
Aug	103.0
Sep	67.8
Oct	traces
Nov	traces
Dec	traces
Total	203.4

Table 2. Performance of 12 short-duration pigeonpea genotypes, Wad Medani, Sudan, 1993.

Genotype	Seed yield (t ha^{-1})	100-seed mass (g)	Plant height (cm)	Days to	
				flowering	maturity
ICPL 90028	2.01	10.6	29	87	116
ICPL151	1.45	11.3	43.3	86	121
ICPL 83016	0.84	9.1	43.0	81	115
ICPL 87102	0.60	8.3	45.7	90	120
ICPL 87 B	0.56	10.3	41.0	85	122
ICPL 87091	0.52	8.6	50.7	80	138
ICPL 86005	0.33	10.0	42.0	89	126
ICPL 87 W	0.33	9.9	47.3	88	127
Kat 60/8	0.32	10.0	38.0	88	119
ICPL 86104	0.31	8.5	48.0	87	121
ICPL 90029	0.26	12.1	28.7	113	123
ICPL 87101	0.22	10.1	51.6	111	129
SE	±0.186[1]				

1. Analyzed only for seed yield

Results

Results are shown in Table 2. ICPL 90028 gave the highest seed yield (2.01 t ha^{-1}), followed by ICPL 151 (1.45 t ha^{-1}). Other than these two, only limited variations in seed yield were found among the varieties. Seed size (100-seed mass) ranged from 12.1 g in ICPL 90029 to 8.3 g in ICPL 87102. Most of the varieties had 100-seed mass higher than 9 g. Most varieties flowered in 80-90 days, except for ICPL 90029 (113 days) and ICPL 87101 (111 days). Similar differences were observed among the varieties in days to maturity—while most matured in 120-130 days, ICPL 83016 took 115 days, and ICPL 87091 took 138 days.

Discussion

Variation among varieties with regard to other parameters did not parallel the variation in seed yields. For example, ICPL 90028, despite its higher seed yield, was characterized by short plants, implying low straw and probably low chaff yields. However, it was characterized by large seeds and relative earliness in both flowering and maturity. ICPL 151 ranked second in both seed yield and seed size, and was characterized by relative earliness and relatively tall plants. In contrast to these high-yielding varieties, ICPL 90029, despite its lower seed yield, had large seeds, and was characterized by short plants and late flowering and maturity.

In general, pigeonpea in this experiment was grown below the optimum population for irrigated areas. For instance, the recommended plant population is 219 000 plants ha^{-1} for the two commonly grown legumes, groundnut and *Lablab purpureus.* The canopy structure of pigeonpea suggests that it could be grown at populations similar to or even higher than these legumes. Pigeonpea thus seems to have very high potential under irrigation if grown at optimum population.

In conclusion, especially since farmers are reluctant to grow forage legumes, pigeonpea can serve as a multipurpose crop suitable for the 168 000 ha earmarked for forage legumes in the Gezira scheme. ICPL 90028 and ICPL 151 showed great potential in terms of seed yield. ICPL 151, however, might be better for seed, stalk, and probably chaff production if grown at optimum population, and can serve as a valuable cash, food, and fodder crop.

Current Status of Pigeonpea Research and Development in Zambia

J Mulila-Mitti[1], K MuiMui[2], and K Kanenga[2]

Introduction

Pigeonpea research conducted at the Msekera Research Station in Zambia has resulted in the identification of two promising medium-duration lines, ICP 7035 and 423/50/3. These are currently being tested in on-farm trials.

Evaluation of short- and extra short duration genotypes was initiated at the Msekera Research Station in 1992/93 (Mulila-Mitti 1994) and extended to the Golden Valley Research Centre in the 1993/94 season.

Rainfall was below average in 1993/94. The rains came late and the distribution was erratic. At Msekera, the total rainfall was 559.5 mm, which is slightly above 50% of normal. At Golden Valley, total rainfall was 614 mm, lower than the average annual rainfall of 800 mm. As most of the rain fell between Dec and Feb, with extremely long dry spells in Mar and Apr, podding was severely affected.

In addition to the research work, other activities on pigeonpea development in Zambia are seed multiplication, extension and training, and utilization of pigeonpea. This paper discusses pigeonpea research and development activities conducted during the 1993/94 season.

On-station trials at Msekera

During the 1993/94 season, a total of seven trials were sown at the Msekera Research Station. At the time of reporting only three trials had been harvested: the Extra Short Duration Pigeonpea International Trial, Short-duration Pigeonpea International Trial, and Regional Short-duration Pigeonpea Trial. A crop from the 1992/93 Long-duration Pigeonpea International Trial was also harvested; it had been left in the field after its first year as it did not give any reportable data.

On-station trials at Golden Valley

Pigeonpea trials were conducted at the Golden Valley Research Centre for the first time. Three trials were sown. Data for the extra short duration trial are not reported

1. Mt Makulu Research Station, Private Bag 7, Chilanga, Zambia.
2. Msekera Research Station, P O Box 510089, Chipata, Zambia.

here as the trial was abandoned after a large portion was washed away by floods. Yields at Golden Valley were higher than those at Msekera.

Extra Short Duration Pigeonpea International Trial

This trial was conducted at Msekera in both 1992/93 and 1993/94. It consisted of 20 entries sown in a randomized block design with three replications. Results for 1993/94 are shown in Table 1. Yields were generally lower in 1993/94 than in the previous year (mean yield 581 kg ha^{-1} vs 836 kg ha^{-1}). The highest yielder was ICPL 84023, with 967 kg ha^{-1}. (It ranked fourth in 1992/93 with 1.30 t ha^{-1}.) The next best entries were ICPL 90001 (875 kg ha^{-1}) and ICPL 89027 (746 kg ha^{1}).

Most of the entries in this trial were small-seeded, with the average 100-seed mass being 9.5 g. ICPL 90011 (11.3 g) had the highest 100-seed mass, and ICPL 4 (6.9 g) the lowest.

Table 1. Performance of 20 genotypes in the Extra Short Duration Pigeonpea International (Determinate) Trial, 1993/94, Msekera Research Station, Zambia.

Genotype	Days to 50% flowering	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 84023	54	7.4	0.97
ICPL 90001	57	9.9	0.88
ICPL 89027	55	10.8	0.75
ICPL 90005	51	9.9	0.70
ICPL 88009	66	9.3	0.67
ICPL 90004	54	9.7	0.65
ICPL 85010	53	9.1	0.65
ICPL 89024	52	10.0	0.65
ICPL 90028	54	9.8	0.59
ICPL 88001	57	10.1	0.59
ICPL 90012	55	9.7	0.58
ICPL 4	56	6.9	0.54
ICPL 90011	55	11.3	0.50
ICPL 88015	55	8.4	0.49
ICPL 88003	51	10.0	0.46
ICPL 89020	51	9.2	0.44
ICPL 88007	53	9.4	0.44
ICPL 88017	61	9.4	0.42
ICPL 83015	59	9.3	0.35
ICPL 87095	53	10.7	0.31
Mean	55.12	9.50	0.58
CV (%)	3.40	5.77	39.35
SE±	1.08	0.32	0.132
LSD (0.05)	3.10	0.91	0.378

Table 2. Performance of 18 genotypes in the Short-duration Pigeonpea (Indeterminate) Trial at two locations in Zambia, 1993/94.

	Days to 50% flowering		100-seed mass (g)		Grain yield (t ha^{-1})	
Genotype	Msekera	Golden Valley	Msekera	Golden Valley	Msekera	Golden Valley
ICPL87115	70	64	9.0	8.8	1.54	1.66
ICPL 90044	67	69	9.5	8.8	1.34	2.23
ICPL 90050	67	64	9.2	9.0	1.27	1.92
ICPL 86015	66	59	9.7	9.7	1.25	2.02
ICPL 86023	68	62	12.0	11.3	1.12	1.73
ICPL 87114	64	60	10.8	10.0	1.09	1.51
ICPL 88034	69	67	9.7	8.9	1.08	2.27
Upas 120	67	62	8.7	8.2	1.06	1.96
ICPL 90048	64		10.3		1.00	
ICPL 85045	68	61	10.1	9.3	1.00	2.37
ICPL 90046	67	62	10.3	9.5	0.91	1.31
ICPL 89018	67	63	10.0	11.3	0.90	1.84
ICPL 89007	68	64	12.8	10.9	0.84	1.42
ICPL 90054	70	69	11.0	9.0	0.73	1.82
ICPL 90053	70	61	10.7	10.5	0.63	1.69
ICPL 90045	65	60	11.3	9.7	0.52	1.58
ICPL 90043	66	59	10.2	8.9	0.40	1.67
ICPL 90052	69	65	10.6	9.2	0.24	0.80
Mean	67.3	63.0	10.33	9.6	0.94	1.74
CV(%)	2.36	5.53	6.65	6.85	41.68	27.44
SE±	0.92	2.00	0.40	0.38	0.226	0.276
LSD (0.05)	2.63	5.7	1.14	1.09	0.650	0.794

The plants were generally short; the tallest was ICPL 88017 (130 cm) and the shortest ICPL 89020 (58 cm). The trial mean height was 75 cm. Generally all the entries were in full bloom before the end of the second month, giving an average of 55 days to flowering.

Some of the lines will be chosen for on-farm testing in the valley areas of Eastern and Southern Provinces.

Short-duration Pigeonpea International Trial

Eighteen entries were tested in this trial, conducted at Msekera in 1992/93 and 1993/94, and at Golden Valley in 1993/94. Results for 1993/94 are shown in Table 2. Some of the lines will be chosen for future on-farm testing in the valley areas of Eastern and Southern Provinces.

Msekera. Most entries performed well at Msekera in both years and thus seem to have potential. This year's yields (mean 940 kg ha^{-1}) were lower than in the previous season due to a dry spell in Feb-Mar. The highest yielders at this location were ICPL 87115 (it was the second highest in 1992/93) with 1.54 t ha^{-1} and ICPL 90044 with 1.34 t ha^{-1}. The lowest was ICPL 90052 (which was also the lowest in 1992/93) with 242 kg ha^{-1}. Seed sizes at Msekera were generally small: 100-seed mass ranged from 12.8 g in ICPL 89007 to 8.7 g in Upas 120. The location mean was 10.3 g 100 seed^{-1}.

The location mean height was 134 cm; ICPL 88034 was the tallest at 155 cm and ICPL 90052 the shortest at 92 cm. The earliest entries to flower were ICPLs 90048 and 87114 (64 days after sowing), and 87115, 90054, and 90053 (70 days).

Golden Valley. The mean yield of 1.74 t ha^{-1} was higher than that recorded at Msekera (940 kg ha^{-1}). The highest-yielding entry (ICPL 85045, with 2.37 t ha^{-1}) did not significantly outyield the second highest yielder. The location mean for days to flowering was 63 days, which is lower than the Msekera mean for 2 years of testing. Flowering at Golden Valley was quickest in ICPL 86015 and ICPL 90043 (59 days), while ICPL 90054 and ICPL 90044 (69 days) were the slowest to flower. The mean 100-seed mass was 9.6 g (range 8.2-11.3 g), lower than at Msekera during the two seasons of testing.

Conclusions. The mean yield at Golden Valley was higher than that at Msekera. ICPL 88034, the top yielder at Msekera in 1992/93 with 3.49 t ha^{-1}, ranked second at Golden Valley (not significantly below the best yielder) in 1993/94. ICPL 90044, the third highest yielder (2.23 t ha^{-1}) at Golden Valley, also performed well at Msekera, where it ranked second in 1993/94 and third in 1992/93. The lowest yielding entry at Golden Valley, ICPL 90052, was also the lowest at Msekera in both 1992/93 and 1993/94. These observations indicate some consistency in the performance of some of the short-duration genotypes tested.

Regional Preliminary Short-duration Pigeonpea Trial

Twelve entries were evaluated in this trial at Msekera and Golden Valley; this was the first season of testing at both locations. Results are shown in Table 3.

Msekera. Yields were rather low compared to the other short-duration trials. Although the trial looked very good and set a large number of pods, pod filling was very poor because of a dry spell soon after flowering. The location mean yield was 438 kg ha^{-1} with the highest yielder, ICPL 86005, giving 620 kg ha^{-1} and the lowest, ICPL 88027,97 kg ha^{-1}. However, ICPL 86005 did not significantly outyield the three next best entries (ICPLs 87101, 86012, and 87105). Seed sizes were relatively larger than in other trials, with a mean 100-seed mass of 12.6 g. The largest seeds were of ICPL 90029 (15.6 g 100 seed^{-1}).

Table 3. Performance of 12 genotypes in the Regional Preliminary Short-duration Pigeonpea Trial at two locations in Zambia, 1993/94.

	Days to 50% flowering		100-seed mass (g)		Grain yield (t ha*^{1})	
Genotype	Msekera	Golden Valley	Msekera	Golden Valley	Msekera	Golden Valley
ICPL 86005	67	70	12.9	11.9	0.62	1.72
ICPL 87101	70	72	12.8	13.1	0.61	1.74
ICPL 86012	59	70	12.5	11.6	0.61	0.94
ICPL 87105	69	73	11.1	10.4	0.58	1.52
ICPL 90029	67	68	15.6	13.9	0.54	1.74
ICPL 83024	61	70	14.8	13.0	0.46	1.23
ICPL 87104	60	61	12.5	12.0	0.45	0.94
ICPL 88023	66	67	12.5	12.6	0.36	1.51
ICPL 90024	69	73	10.6	10.5	0.36	0.84
ICPL 87	62	69	11.4	10.3	0.35	1.18
ICPL 90028	67	67	14.0	13.3	0.22	1.41
ICPL 88027	*66*	*61*	10.3	10.4	0.10	1.27
Mean	64.7	68.0	12.59	11.90	0.44	1.34
CV(%)	2.55	7.14	4.73	4.78	45.61	17.87
SE±	0.95	2.79	0.34	0.33	0.115	0.138
LSD (0.05)	2.80	8.19	1.01	0.96	0.338	0.405

The tallest entry at this location was ICPL 86005 (122 cm), and the shortest was ICPL 86012 (83 cm). The location mean height was 102 cm. The mean number of days to flowering was 65 (range 59-70 days). This trial will be repeated next season to further evaluate the potential of these materials.

Golden Valley. Mean yield at Golden Valley was 1.34 t ha^{-1}; nine entries recorded yields above 1 t ha-^{1}. The highest yielder was ICPL 90029 (1.74 t ha-^{1}), which significantly outyielded six of the 12 entries at this location. ICPLs 87101, 86005, and 87105 were the other top yielders in this trial; these three genotypes were also among the four top yielders at Msekera.

Plant height at Golden Valley ranged from 73 to 101 cm, with a mean of 85.7 cm. This was markedly lower than at Msekera (101.7 cm). Days to 50% flowering ranged from 61 to 73 days with a mean of 68 days, similar to the figures for Msekera.

Long-duration Pigeonpea International Trial (1992-94)

This trial, consisting of 18 entries, was sown at Msekera in 1992/93. It did not do well in its first season and no yield data were recorded. In the second year, rather clean but somewhat low yields were obtained. The top yielders were ICPL 87126 with

Table 4. Performance of 18 genotypes in the Long-duration Pigeonpea International Trial, 1993/94, Msekera Research Station, Zambia.

Genotype	Days to 50% flowering	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 87126	174	12	0.55
Bahar	175	11	0.55
PR 5149 Sel	173	8	0.51
ICPL 87133	174	10	0.46
ICPL 88055	174	12	0.43
ICPL 84072	175	11	0.41
ICPL 90107	177	11	0.35
ICPL 87132	174	11	0.30
Gwalior 3	175	11	0.29
ICPL 11207	175	10	0.29
ICP 9174	176	11	0.25
ICPL 87143	176	11	0.25
T-7	174	12	0.21
ICPL 366	175	11	0.21
ICPL 90108	177	11	0.18
ICPL 90109	174	11	0.18
ICPL 88069	175	11	0.15
ICPL 90110	175	12	0.03
Mean	174.81	10.86	0.41
CV (%)	0.95	6.85	69.59
SE±	0.83	0.37	0.108
LSD (0.05)	2.35	1.06	0.308

554 kg ha^{-1} and Bahar (548 kg ha^{-1}). The trial mean yield of 411 kg ha^{-1} was far below the potential of these lines. However, the harvested seed was free from diseases and showed very little insect damage.

The high CV of about 70% for yield in this trial indicates the great variation in the suitability of different genotypes as ratoon crops. It can be tentatively concluded that the low yielders are not good for ratooning, while those genotypes that yielded above 500 kg ha^{-1} are suitable for ratoon cropping.

These genotypes are good for soil fertility improvement, and the best entries should be further evaluated by the agroforestry research team.

On-farm varietal evaluation

Evaluation of ICP 7035, 423/50/3, NPP 670, and HY 3C on farmers' fields was conducted for the second year in Eastern Province. Due to severe drought during the season, performance of the 1993/94 on-farm trials was poor, and yields were extremely low on all test farms.

On the other hand, second flush yield data obtained from two on-farm trials sown in 1992/93 were encouraging. Mean yields of the four varieties were 525 kg ha^{-1} and 568 kg ha^{-1} in the two trials. The highest-yielding variety was 423/50/3 (mean yield 854 kg ha^{-1} on the two farms), followed by NPP 670 (751 kg ha^{-1}), HY 3C (371 kg ha^{-1}), and ICP 7035 (261 kg ha^{-1}).

Seed multiplication

A total of 800 kg of ICP 7035 seed has been harvested from the multiplication plot at Golden Valley Research Centre. Most of this seed will be distributed to provincial farming systems research teams and NGOs active in the promotion of pigeonpea in the country. The NGOs are expected to multiply the seed further and distribute it to farmers. In 1994/95, seed of 423/50/3, NPP 670, and HY 3C will be multiplied.

Extension, training, and utilization

In order to create awareness of pigeonpea and increase farm-level production, the Food Legume Project initiated training of extension workers and farmers through formal training workshops and radio and television. Farmers and extension workers were also invited to attend a field day at Golden Valley Research Centre, where pigeonpea trials and a seed multiplication plot were sown.

The project also developed simple but tasty pigeonpea recipes that have been used in cooking demonstrations during training workshops. Some of these recipes were used for pigeonpea preparations exhibited at the 1994 Agricultural and Commercial Show.

The experience gained so far indicates that pigeonpea food preparations made using *dhal* are more palatable than those made using whole seed. It is clear that the development and provision of simple processing tools will facilitate increased consumption and production of pigeonpea.

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Pigeonpea Cultivar Trials in Namibia, 1992-94

D J M Marais[1]

Introduction

Pigeonpea is a new crop in Namibia, and considerably more research is required before the potential of the crop can be realized. In particular, studies are required to:

- Identify adapted varieties in each maturity duration group
- Determine optimum plant population for suitable or promising varieties.

Table 1. Performance of genotypes in the Pigeonpea International Trials at two locations in Namibia, 1992/93.

Mahanene, Extra short duratiion		Mahanene, Short duration	
Genotype	Yield (t ha^{-1})	Genotype	Yield (t ha^{-1})
ICPL 90033	0.25	ICPL 87101	0.40
ICPL 90035	0.25	ICPL 87109	0.30
Upas 120	0.24	ICPL 90028	0.28
ICPL 88032	0.23	ICPL 90029	0.28
ICPL 90032	0.22	ICPL 84031	0.25
ICPL 90039	0.21	ICPL 89030	0.23
ICPL 89011	0.21	ICPL 88023	0.23
ICPL 90030	0.20	ICPL 87	0.20
ICPL 89001	0.17	ICPL 151	0.20
ICPL 89012	0.15	ICPL 83024	0.20
ICPL 90031	0.14	ICPL 86005	0.20
ICPL 90038	0.14	ICPL 86012	0.19
ICPL 88039	0.13	ICPL 87105	0.18
ICPL 90036	0.12	ICPL 87104	0.14
ICPL 87111	0.10	ICPL 90024	0.14
ICPL 89008	0.10	ICPL 88027	0.14
ICPL 4	0.10	ICPL 89031	0.11
ICPL 89004	0.04	ICPL 88025	0.10
		ICPL 90031	0.10
Mean	0.17	ICPL 85012	0.07
SE	± 0.015		
CV(%)	65.80	Mean	0.20
		SE	±0.011
		CV(%)	50.90

Continued....

1. Ministry of Agriculture, Water and Rural Development, P O Box 788, Grootfontein, Namibia.

Table 1. *Continued....*

Bagani, Medium duration		Bagani, Long duration	
Genotype	Yield (t ha^{-1})	Genotype	Yield (t ha^{-1})
ICPL 90104	3.64	ICPL 88069	4.08
ICPL 487	3.35	ICPL 366	3.95
ICPL 90103	3.31	ICP9174	3.64
ICPL 89049	3.12	PR 5149 Sel	3.61
ICPL 90100	2.90	ICPL 84072	2.67
BDN1	2.62	ICPL 87126	2.58
C 11	2.51	T7	2.26
ICPL 90096	2.48	ICPL 87132	2.11
ICPL 90098	2.48	ICPL 90107	1.92
ICPL 90102	2.38	ICPL 90110	1.84
ICPL 89046	2.33	ICPL 90108	1.74
ICPL 90101	2.27	Gwalior 3	1.66
ICPL 90097	2.24	ICPL 11207	1.65
ICPL 89048	2.10	ICPL 90109	1.60
ICPL 90099	2.02	Bahar	1.58
ICPL 90094	0.57	ICPL 88055	1.56
Mean	2.53	ICPL 87143	1.30
SE	±0.236	ICPL 87133	1.25
CV (%)	55.98	Mean	2.28
		SE	±0.283
		CV (%)	68.99

Results and discussion

During the past two seasons (1992/93 and 1993/94) only cultivar evaluation has been done. The results of these trials are shown in Tables 1 and 2. On the basis of these results, it is suggested that sowing densities between 15 000 and 30 000 plants ha^{-1} would be appropriate.

1992/93 season. Trials were conducted at two locations, Mahanene and Bagani. Eighteen extra short duration and 20 short-duration cultivars were tested at Mahanene, and 16 medium-duration and 18 long-duration cultivars at Bagani. There were considerable variations in yield, and CVs for the trial were unacceptably high. On the whole, however, the medium- and long-duration cultivars performed better.

Seven of the 16 medium-duration cultivars and 6 of the 18 long-duration cultivars gave yields above 2.5 t ha-^{1}. However, long-duration cultivars would be susceptible to frost at Bagani; short-duration types would be more suitable. The poor performance of the extra short and short-duration cultivars at Mahanene was due to the very dry environment and to severe insect pest pressure (no control measures were taken).

Table 2. Performance of 20 pigeonpea genotypes in the Regional Preliminary Observation Nursery, Uitkomst, Namibia, 1993/94.

Genotype	Yield (kg ha^{-1})	Genotype	Yield (kg ha^{-1})
HY3C-1	235.03	9247-24	48.03
HY 3C-2	149.51	9246-12	37.17
9254-1	122.04	9232-1	36.18
9247-1	107.40	9246-11	33.72
9251-19	89.80	8002-3	28.45
9246-22	72.04	9202-1	28.29
9253-4	69.57	Luwe 1-5	27.47
9246-3	57.57	9247-3	15.13
9246-1	55.10	9244-25	
9252-1	53.95	Sample 6-3	

1993/94 season. Five trials were sown: one at Uitkomst Research Station and two each at Mahanene and Bagani. Due to heavy frost, however, the latter four trials were destroyed and no seeds were formed; only the trial at Uitkomst was harvested (Table 1).

Conclusion and recommendations

The trial at Uitkomst was sown on 1 Dec 1993. The period from mid Sep to mid May is usually frost-free, but this season was the coldest in 30 years, and frost set in early, severely reducing yields in the trial.

On the basis of these results, three cultivars are recommended for further testing: 9254-1, HY 3C-2, and HY 3C-1. It is also important to control insects (by spraying) at the flowering stage.

Pigeonpea Research in Lesotho During the 1993/94 Season

S S Moima[1]

Introduction

In recent years, Lesotho has been experiencing changed climatic conditions: warm, short summers with limited rainfall (800-900 mm) and cold, long, dry winters. As a result most farmers prefer short-duration crops that can fit into the production system. Crop failures are common due to frequent drought and continuous sole maize cropping systems. Therefore, it is imperative to introduce a new leguminous crop (e.g., pigeonpea) that can improve soil fertility, withstand drought, and also improve nutrition in rural communities. Pigeonpea research in the 1993/94 season focused on varietal evaluation, with the following objectives:

- To identify adaptable, high-yielding, short- and medium-duration varieties
- To provide crop diversity in order to improve productivity and alleviate constraints.

Methodology and results

Twelve short- and medium-duration varieties were tested. Each was sown in two 5 m long rows, spaced at 45 x 20 cm. Mixed fertilizer (2-3-2(22)+Zn) was applied at sowing, @ 320 kg ha^{-1}. The varieties were sown on 8 Dec 1993. Data were collected on sowing date, emergence date, monthly rainfall and temperature, days to 50% flowering, and pest and disease incidence.

Both trials were caught by frost before harvest, and yielded no grain. CMR beetles damaged some of the flowers. Dates of 50% flowering were 2 Feb for the short-duration varieties and 20 Feb for the medium-duration varieties.

Conclusion and recommendations

Short-duration cultivars would be more suitable for Lesotho than medium-duration ones. Sowing date is critical—these trials were sown in early Dec, which was too late. It is recommended that future trials be sown in early or mid Oct in order to obtain acceptable yields.

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Pigeonpea Evaluation in Swaziland

Z Mamba[1], S N Silim[2], and S Tuwafe[3]

Introduction

Grain legume crops are important sources of high-quality protein in the human diet. They are also important components of sustainable agriculture in rainfed areas. Drought is the most important constraint limiting crop production in such environments. It is therefore important to evaluate grain legumes for adaptation to drought-prone environments; especially pigeonpea, which has been found to be tolerant of such conditions.

A number of nurseries were received from the Pigeonpea Project and from ICRISAT/EARCAL, Kenya. They included:

- Four sets of short-duration varieties
- Two sets of long-duration varieties
- One observational trial.

The objective of this study was to introduce and screen pigeonpea genotypes for adaptation within Swaziland climatic conditions, with respect to yield and disease/insect pest tolerance.

Short-duration genotypes

Pigeonpea Project Nursery. Twelve short-duration genotypes obtained from the Pigeonpea Project in Malawi were evaluated at two locations, Luve (dry Middleveld) and Big Bend (Lowveld). Spacing was 90 x 10 cm. Plot size was four rows of 4 m length, replicated three times. Basal fertilizer was applied @ 150 kg ha^{-1} of 2:3:2(22) + 0.05% Zn at sowing. Nitrogen topdressing was not applied. Hand-hoe weeding was done once. These nurseries were sown on 20 Jan at Luve and 6 Feb 1994 at Big Bend. Spraying for insect control was timely at Big Bend, but late at Luve.

Plant emergence was good at Big Bend, but termites became a major problem later.

There were significant differences among genotypes at both locations (Table 1). However, yields were affected by late sowing, especially at Luve.

ICRISAT Nursery. The ICRISAT/EARCAL Program, Nairobi, sent two sets (18 genotypes) which were sown at two locations: Luve on 13 Dec and Malkerns on 20 Dec 1994. Spacing was 75 x 10 cm. Plot size was four rows of 4 m length, with three

1. Malkerns Research Station, P O Box 4, Malkerns, Swaziland.
2. ICRISAT Pigeonpea Project, P O Box 39063, Nairobi, Kenya.
3. ICRISAT Pigeonpea Project, P O Box 1096, Lilongwe, Malawi.

Table 1. Grain yields (t ha^{-1}) from short-duration pigeonpea genotypes grown at Malkerns, Luve, and Big Bend, Swaziland, 1993/94.

Genotype	Malkerns[1]	Luve[1] (sown 13 Dec)	Luve[2] (sown 20 Jan)	Big Bend[2]
ICPL 87101	1.03	1.47	0.15	0.97
ICPL 86005	1.05	1.33	0.36	0.88
ICPL 87104	0.80	1.49	0.29	0.88
ICPL 86012	1.46	1.18	0.30	0.77
ICPL 88027	0.81	1.20	0.31	0.75
ICPL 78 W	0.72	1.09	0.22	0.70
ICPL 90028	1.08	0.90	0.24	0.68
ICPL 83024	1.22	1.49	0.23	0.67
ICPL 87105	1.04	0.82	0.13	0.66
ICPL 88023			0.34	0.66
ICPL 90029	1.61	0.97	0.18	0.64
ICPL 90024	0.88	1.56	0.35	0.54
ICPL 87091	0.81	0.75		
ICPL 90013	1.30	1.43		
ICPL 90001	0.75	0.99		
ICPL 87109	1.38	1.12		
ICPL 87115	1.24	1.14		
ICPL 90050	0.92	1.41		
Kat 60/8	1.03	1.00		
Mean	1.07	1.19	0.26	0.74
SE±	ns	ns	0.015	0.020
CV (%)	30.9	31.0	34	39

ns = not significant.
1. Material from ICRISAT Nursery, Kenya.
2. Material from ICRISAT Pigeonpea Project Nursery, Malawi.

with three replications. Basal fertilizer (2:3:2(22) + 0.05% Zn) was applied @ 200 kg ha^{-1} at Malkerns and 150 kg ha^{-1} at Luve. Insect control was done somewhat late at Luve and later still at Malkerns.

Pod and grain yields were high at Malkerns, with 11 genotypes producing grain yields above 1 t ha^{-1}. The best yielders were ICPL 90029 (1.61 t ha^{-1}) and ICPL 86012 (1.46 t ha^{-1}) (Table 1).

Yields were similarly high at Luve, with 13 genotypes yielding above 1 t ha^{-1}. However, ranking of the varieties was different at the two locations: with the exception of ICPL 86012, the poor yielders at Malkerns (moist Middleveld) were the highest yielders at Luve (dry Middleveld). The elevation, soil texture, and temperature may have affected the performance of these genotypes.

Conclusions. Dec plantings at Malkerns and Luve gave average grain yields of above 1 t ha^{-1}, while Jan plantings at Luve and Big Bend produced averages of only 260 and

Table 2. Grain and pod yields from 12 long-duration pigeonpea varieties, Big Bend, Swaziland, 1993/94.

Genotype	Pod yield (t ha-1)	Grain yield (t ha1)
QP14	1.15	0.87
ICP9145	1.43	0.80
PGM 9208	1.38	0.79
PGM 9245	1.23	0.69
QP38	1.14	0.68
PGM 9227	1.11	0.63
HY3C	1.04	0.61
PGM 9201	1.00	0.61
Royes	0.97	0.60
QP37	1.47	0.60
QP15	0.96	0.58
Line25	0.91	0.48
Mean	1.15	0.66
SE±	ns	ns
CV(%)	44	39

ns = not significant.

740 kg ha^{-1}, respectively. This shows that early sowing (Nov-Dec) would significantly improve grain yields. ICPL 86005 and ICPL 87104 seemed to be better adapted to drier environments (Luve and Big Bend), while other genotypes (e.g., ICPL 90029) appeared more suited to moist areas (Malkems). ICPL 86012 showed good performances at all locations.

Six genotypes (ICPLs 86005, 86012, 87104, 87109, 90024, and 90029) will be further tested during the 1994/95 cropping season.

Long-duration genotypes

Twelve genotypes were evaluated in a nursery sown at Big Bend on 6 Jan 1994. Spacing was 90 x 40 cm. Crop management practices were similar to those in the short-duration evaluations.

These varieties matured later than the short-duration varieties, and were therefore affected by low temperatures and frost in Jun.

There was no significant difference in grain yield between genotypes (Table 2). Grain yields ranged from 0.48 to 0.87 t ha^{-1}, QP 14 being the highest yielder. Six genotypes (QP 14, QP 38, ICP 9145, PGM 9208, PGM 9245, and HY 3C) will be further evaluated in the 1994/95 season.

Processing and Utilization of Pigeonpea

Umaid Singh[1]

Introduction

Grain legumes are becoming increasingly popular in the daily diet of people, particularly in developing countries, where they are a major source of proteins and minerals. Pigeonpea, also called red gram, is among the important grain legumes in the tropics and semi-arid tropics. India accounts for about 85% of the world's production (and consumption) of pigeonpea. Other countries where pigeonpea is important are Australia, Kenya, Malawi, Myanmar, the Philippines, Tanzania, Thailand, and Uganda.

Processing and utilization are critical aspects of postharvest handling. Pigeonpea seeds, like those of other legumes, have a fibrous seed coat also known as the husk, hull, or skin. This seed coat is indigestible and sometimes bitter in taste. In addition, it consists mainly (80-90%) of polyphenols, which adversely affect nutritional quality (Singh 1993). Removal of the seed coat improves not only the appearance, palatability, and cooking quality, but also digestibility and nutritive value.

Dehulling of pigeonpea is therefore of vital importance if utilization of the crop is to be increased. Pigeonpea can be processed either as green seed or as dry seed. Various processing methods under each of these two broad categories are discussed below.

Processing of green seeds

In some developing countries, pigeonpea is harvested at the green-pod stage for vegetable use. The harvested pods are shelled and cooked; i.e, processing is done entirely at household or village level. In some Caribbean countries, commercial-scale canning of green pigeonpeas, mainly for export, is an important industry. For example, in the Dominican Republic about 80% of the annual harvest of green pigeonpea is canned and exported (Mansfield 1981). Although the quality of green seed depends mainly on its maturity and the agroclimatic environment, cultivars suitable for canning have been developed. Cultivars with large, uniform, bright green seeds and pods at the green developing stage are preferred for canning. Green seed is more nutritious than dry seed because it is more digestible and contains more protein and fat (Faris et al. 1987). Green seeds with a higher content of soluble sugars taste sweeter and are preferred by consumers, but genotypes with this trait have not yet been developed for cultivation. Large-scale processing of green seeds involves several operations in-

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cluding cleaning, blanching, and filling (in cans or polyethylene bags). To obtain a high-quality canned product, it is important that the seeds be harvested at a uniform stage of maturity.

Processing of dry seeds

Primary processing (dehulling). Primary processing, also called dehulling, converts whole seed into *dhal* (dry split cotyledons). Over 90% of the pigeonpea produced in India is dehulled. The dehulling operation is usually performed in two steps: first loosening the husk from the cotyledons, and then removing the husk and splitting the cotyledons using a suitable machine depending on the quantity of material to be processed.

Dehulling pigeonpea is an age-old practice in India. In earlier days hand-pounding was common; this was later replaced by stone *chakkis.* Several traditional methods are used that can be broadly classified into two categories: the wet method (soaking in water, sun-drying, and dehulling) and the dry method (oil/water application, sun-drying, and dehulling).

Small-scale dehulling. For small-scale dehulling, the basic unit is a *chakki,* a quern consisting of two grinding stones, the lower one fixed and the upper one rotating. It is operated manually and used mainly to dehull small quantities of pigeonpea for home consumption in India. Pre-dehulling treatments vary from region to region. In some regions, pigeonpea is soaked in water for 2-14 h, whereas in others the seed is treated with oil before dehulling. In some parts of India pigeonpea is also heated before dehulling. In some households, pigeonpea is first split using a *chakki,* then treated with oil/water, and finally hand-pounded to remove the seed coat. In some African countries, pigeonpea is split using grinding stones and partially dehulled by hand-pounding in a wooden mortar and pestle.

Large-scale dehulling. To dehull large quantities of pigeonpea into *dhal,* a mechanically operated *dhal* mill is used. The material is first graded and then passed through a roller that causes mild abrasion—the tempering operation. This causes partial scarification of the seed coat, enhancing oil/water absorbing efficiency. The pigeonpea is then treated with oil/water and sun-dried before being dehulled in a roller machine. Exact figures are not available, but about 30-40% of Indian pigeonpea production is dehulled by commercial *dhal* mills in cities. It is estimated that 7-8000 *dhal* mills of various capacities operate in India. In recent years, some efforts have been made to develop improved dehulling methods, but these methods have not become popular with agroprocessing units. Additional efforts are needed in this direction.

Dehulling pretreatments

Of all pulses, it is most difficult to remove the seed coat from pigeonpea seeds. Both small-scale and large-scale processing involve a preprocessing treatment to loosen the seed coat before dehulling, and thereby improve *dhal* yields. Several pretreatments are available:

- Soaking in water
- Soaking in sodium bicarbonate solution (2-3% w/v)
- Treatment with edible oil (groundnut, linseed, sesame, sunflower), 0.5-1% w/w
- Heat treatment, heating pigeonpea seed using hot air (70-95°C) and sand roasting (100-125°C).

In addition to the pretreatment, several other factors influence dehulling efficiency and product quality. Of these, seed characteristics (nature of the seed coat, seed shape and size) are important. Further, the chemical constituents of the seed coat (e.g., the gums and non-starchy polysaccharides present in the interspace between the husk and the cotyledons) cause the husk to adhere to the cotyledons (Singh in press, a).

Dehulling losses

Considerable quantitative and qualitative losses occur during dehulling of pulses, depending on the methods used and the seed characteristics. *Dhal* yield is considerably lower in small-scale processing than in large-scale processing (Table 1), probably due to differences in equipment and pre-dehulling treatment methods. Even in commercial *dhal* mills, *dhal* yields only approach 70%, much lower than the theoretical yield of 80-85%, depending on the seed coat contents.

As shown in Table 2, considerable amounts of protein, calcium, and iron—all important dietary nutrients—are lost in the powder fraction during dehulling. Studies have shown that protein and some minerals are concentrated in the outer cotyledon layers, which are lost during dehulling as a result of scarification during the abrasive action.

Table 1. *Dhal* yield losses (%) in pigeonpea.

	Large-scale processing		Small-scale processing	
Fraction	Range	Mean	Range	Mean
Dhal	60-85	70.1	50-80	61.0
Grits	2-10	4.4	5-20	10.6
Powder	9-18	12.8	7-20	12.6
Husk	8-25	12.9	10-25	15.2

Source: Singh in press, b

Table 2. Effect of dehulling on nutrient losses in pigeonpea.

Dehulling time (min)	*Dhal* constituents[1]			Powder constituents[1]		
	Protein	Calcium	Iron	Protein	Calcium	Iron
0	21.4	64.9	5.7			
2	20.8	51.7	4.1	31.2	167.8	17.3
4	20.3	51.1	4.0	29.7	118.8	11.9
8	19.6	45.7	3.6	27.1	94.1	9.2
12	19.6	45.7	3.6	27.1	94.1	9.2
SE±	0.17	2.83	0.19	0.15	2.0	1.63

1. Units: protein in g 100 g^{-1}, calcium and iron in mg 100 g^{-1}

Utilization

Pigeonpea is eaten in various forms. Immature, green, tender pods are cooked and eaten in some Southeast Asian countries. Green seeds are used as a vegetable in India and some African countries. Canned, frozen green seeds are used as a vegetable in parts of the Caribbean and Latin America. In India, whole seed is processed into *dhal,* which is used in a variety of foods. In contrast, consumption of whole, boiled seeds is the major form of pigeonpea utilization in much of Africa. Pigeonpea sprouts are boiled and eaten in India and parts of Southeast Asia. Pigeonpea *tempeh,* a fermented product, is becoming popular in Indonesia, where *tempeh* is traditionally made from soybean. Studies at ICRISAT have shown that pigeonpea has the potential to be used as a source of starch for noodle preparation. More novel food uses of pigeonpea need to be explored and their acceptability studied.

The cooking quality of pigeonpea is primarily assessed by its cooking time. Organoleptic properties such as taste, color, flavor, and texture of the cooked product, collectively referred to as consumer preferences, are also important. *Dhal* cooking time of newly developed genotypes tested at ICRISAT varied from 18 min for ICPL 270 to 27 min for ICPL 87067 (Table 3). Several factors affect cooking time. Our earlier studies (Singh et al. 1984) have shown that short-duration cultivars had better cooking quality than medium- and long-duration types. Our results also indicated that cooking time was positively correlated with seed size, although the magnitude of correlation was low. As shown in Table 3, there were noticeable differences in color, texture, flavor, taste, and general acceptability, suggesting that newly developed cultivars should be monitored for these characteristics. In African countries, where whole seed is cooked and eaten, newly developed cultivars should be similarly tested for cooking quality and consumer acceptability, using whole-seed samples.

Table 3. Cooking quality and sensory evaluation of cooked *dhal* of 10 pigeonpea genotypes.

Genotype	Maturity group	Seed color	100-seed mass[1] (g)	Cooking time[2] (min)	Water absorption[2] ($g\ g^{-1}$)	Dispersed solids[2] (%)	Sensory evaluation[3] Color	Texture	Flavor	Taste	General acceptability
ICPL 87	Early	Brown	10.9	19	2.1	29.0	2.6	3.5	2.5	2.5	2.5
ICPL 151	Early	Cream	9.3	24	1.9	23.5	3.7	3.2	3.0	3.0	3.1
ICPL 270	Medium	Brown	12.4	18	2.3	28.6	2.6	3.5	2.6	2.5	2.6
ICPL 366	Late	Brown	10.4	20	1.9	28.2	3.5	3.2	3.1	2.6	2.8
ICPL 87051	Medium	Cream	14.6	24	1.4	22.5	3.0	2.2	3.2	3.1	3.1
ICPL 87063	Medium	Cream	13.5	26	1.7	22.5	3.0	2.2	3.2	3.1	3.1
ICPL 87067	Medium	Cream	15.1	27	1.7	21.1	2.8	1.9	3.0	2.7	2.7
ICPV 1 (ICP 8863)	Medium	Brown	10.4	21	1.9	29.4	3.5	3.3	3.2	3.4	3.3
C 11	Medium	Brown	11.2	22	1.7	28.9	3.5	2.5	3.2	3.2	3.3
BDN 2	Medium	Cream	7.9	23	1.8	26.9	3.1	2.9	3.1	3.2	3.1
SE ±				0.6	0.05	1.25	0.12	0.08	0.11	0.07	0.09

1. Mean of 5 determinations.
2. Mean of 2 determinations.
3. Mean of scores of 10 panel members on a 1–4 scale where 1 = poor, 4 = excellent.

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Country Workplans

Kenya—Collaborative Research Workplan

The collaborative research workplan for Kenya covers the following main areas:

- On-farm trials
- Seed multiplication
- Back-up research (multilocational varietal trials, screening for disease resistance, insect pest management)
- Processing and utilization.

On-farm Evaluation of Short-duration Pigeonpea

Justification and objectives

Pigeonpea cultivars maturing within 100-150 days have been developed in Kenya and at ICRISAT Asia Center (IAC), India. These cultivars have been widely tested in Kenya and have shown potential for cultivation in dryland areas, with good yields and ratoonability. In areas with bimodal rainfall, two crops can be grown each year, during the short and long rains. We have now identified the three most promising among the short-duration cultivars for testing on farmers' fields. On-farm evaluation began last year; in 1994/95 we plan to expand the work to include more farmers at a larger number of locations. The trial aims at:

- Evaluating the performance of improved cultivars in farmers' fields under rainfed conditions
- Evaluating improved cultivars in farmers' fields under irrigation, specifically for green pods
- Eliciting farmers' reactions to the improved cultivars
- Determining the potential and subsequently monitoring the adoption of these new cultivars.

Methodology

Extension staff, NGOs, and researchers will jointly select the farmers to participate in these trials, which will be sown during the short and long rains of 1994/95. Farmers will also be selected from irrigation schemes in Makindu, Kibwezi, and Mtito Andei to test the potential of pigeonpea for green pod production for export.

Genotypes. Three cultivars; Kat 60/8, ICPL 87091, and ICPL 87109.

Locations. For rainfed on-farm trials, locations have been selected in different agroecological zones as shown in Table 1.

Design. Randomized block with two replications. Plot size 10 x 10 m. Spacing 50 x 20 cm, 2 plants $hill^{-1}$.

Table 1. Locations for on-farm trials of rainfed pigeonpea, Kenya, 1994/95.

Agroecological zone	Cultivars	District
LM 4 (Wote)	Kat 60/8, ICPL 87091, ICPL 87109	Makueni
UM 4 (Kiumtwa)	Kat 60/8, ICPL 87091, ICPL 87109	Machakos
UM 5 (Makindu)	Kat 60/8, ICPL 87091, ICPL 87109	Makueni
CL 2-4 (Matuga)	ICPL 87091, ICPL 87109	Kwale
CL 4 (Bahari)	ICPL 87091, ICPL 87109	Kilifi
CL 4 (Kaloleni)	ICPL 87091, ICPL 87109	Kilifi
CL 4 (Bamburi)	ICPL 87091, ICPL 87109	Mombasa

Data. Sowing and weeding dates, phenology, yield, farmers' preferences, socio-economic data.

Expected outputs

- Performance evaluation of the short-duration cultivars in different agroecological zones under farmer management
- Identification of farmers' preferences for variety, seed size, plant height, and maturity duration
- Evaluation of socioeconomic factors relating to the improved cultivars
- Recommendations on variety release (s)
- Monitoring adoption of new varieties.

Budget

	Funding (US$) by Project[1]
Travel and allowances	1600
Operational costs	
Chemicals, fertilizer, etc.	700
Supplies	150
Communication	50
Support to extension staff	300
Total	**2800**

1. Details of NARS funding will be provided later.

Seed Multiplication

Justification and objectives

Once improved cultivars are identified, large quantities of seed should be available within the country for on-farm testing, demonstrations by extension staff, and most importantly, for distribution to farmers who frequently visit research stations and ask for improved seed. During 1993/94, we bulked about 400 kg of various varieties, all of which was distributed. The purpose of this exercise is to further increase seed of promising cultivars for experimental purposes, on-farm testing, demonstrations, and future release.

Methodology

Genotypes. Bulking of pre-release cultivars: Kat 60/8, Kat 777, Kat 81/3/3, ICPL 87091, ICPL 87109, NPP 670, and Kioka. Seed increment of elite lines: 20 cultivars.

Location. Katumani.

Plot size. Half hectare for each pre-release cultivar, 10 m x 10 rows for each elite line.

Expected outputs

- 500-1000 kg of each pre-release line
- 50-100 kg of each elite line
- Long-term output: increased area under improved cultivars.

Budget

	Funding (US$) by Project[1]
Travel	100
Land preparation	100
Communication	100
Labor	600
Chemicals, supplies, etc.	400
Total	**1300**

1. Details of NARS funding will be provided later.

Back-up Research

Back-up research involves evaluation of short-, medium-, and long-duration varieties, screening for disease resistance, and development of an integrated pest management package.

Multilocational Varietal Trials

Justification and objectives

Several elite lines have shown promise in preliminary yield trials in Kenya. These lines need to be tested further in different environments to identify their areas of adaptation. The trials aim at evaluating newly developed lines of different maturity groups in different agroecological zones to fit them in areas where they are best adapted.

Methodology

Genotypes. Forty five lines of short-, medium-, and long-duration varieties (15 lines in each nursery), plus controls for each maturity group.

Locations. Katumani (UM 4 zone), Kiboko (LM 5-6 zones), and Kampi ya Mawe (UM 5 zone).

Design. Randomized complete block with three replications. Plot size: five rows 5 m long. Spacing: 40 x 10 cm for short-duration, 80 x 50 cm for medium-duration, and 80-100 x 50 cm for long-duration varieties.

Data. Sowing date, phenology, yield and yield components, and weather data.

Expected outputs

- Determination of yield
- Better understanding of the phenological responses of each maturity group in different agroecological zones
- Identification and on-farm testing of 1-2 lines for each agroecological zone.

Budget

	Funding (US$) by Project[1]
Travel	
Transport and allowances	150
Operational costs	
Labor	200
Supplies (chemicals)	200
Supplies (bags)	100
Reporting and publications	50
Total	**700**

1. Details of NARS funding will be provided later.

Screening for Resistance to Fusarium Wilt and Cercospora Leaf Spot

Justification and objectives

Surveys have indicated that fusarium wilt and cercospora leaf spot are the major pigeonpea diseases in Kenya. Plant losses due to fusarium wilt often exceed 10% and may reach 90% in some areas. Yield losses due to cercospora vary, and 80% loss has been reported in severe cases. The study aims to screen breeding lines for wilt and leaf spot resistance. Wilt screening will be continued at Katumani and Kiboko. In addition, screening for combined resistance to both diseases will be initiated at Katumani during the 1994/95 season.

Methodology

Genotypes. Germplasm and breeding lines.

Locations. Wilt sick plots at Katumani and Kiboko.

Design. 4 m x 1 row in two replications.

Data. Days to emergence, flowering, and maturity; number of plants at emergence and number of wilted plants after every 10 days; cercospora leaf spot score at 50% flowering (Katumani).

Expected output

- Identification of lines resistant to both fusarium wilt and cercospora leaf spot.

Budget

	Funding (US$) by Project[1]
Labor	300
Supplies	200
Transport	200
Total	700

1. Details of NARS funding will be provided later.

Development of a Regional Fusarium Wilt Nursery

Justification and objectives

Earlier studies have indicated that pigeonpea cultivars that have shown resistance to fusarium wilt at IAC showed variability in wilt reaction when tested in the eastern and southern Africa region. There are probably differences in the pathogenicity of *Fusarium udum* Butler in different environments. We have constituted a nursery consisting of genotypes with known reactions to the pathogen for testing in Kenya, Malawi, Tanzania, and India initially to determine whether there are race differentials in fusarium wilt. Development of the nursery will enable us to obtain a clearer idea of pathogenic variability in F. *udum.*

Methodology

Genotypes. Improved lines from Kenya, Malawi, Tanzania, and India.

Locations. Kenya - Katumani and Kiboko; Malawi - 2 sites; Tanzania - 1 site; India -IAC.

Design. Plot size 4 m x 1 row in two replications.

Data. Days to emergence, flowering, and maturity; number of plants at emergence and number of wilted plants after every 10 days.

Expected outputs

- Determination of pathogenic variability of *F. udum*
- Performance evaluation of improved lines in various regions.

Budget

	Funding (US$) by Project[1]
Labor	250
Supplies	150
Transport and communication	100
Total	500

1. Details of NARS funding will be provided later.

Seasonal Distribution of Podfly, Pod-sucking Bug, and *Helicoverpa* in Eastern Kenya

Although the podfly, pod-sucking bugs, and *Helicoverpa armigera* are major pests of pigeonpea, information on damage levels and seasonal distribution of these pests is not available. This information is critical; once obtained, it can be used as a baseline to develop effective pest management practices.

Methodology

Surveys. Four during the cropping season, at the vegetative, flower initiation, podding, and harvest stages.

Design. Randomized block with four replications.

Data. Rainfall, temperature, trapped populations (using pheromones for *Helicoverpa,* sticky traps for podfly, and pitfalls for predators).

Expected output

- Information on occurrence and distribution of *Helicoverpa,* podfly, and pod-sucking bugs.

Budget

These studies will be conducted depending on the availability of funds.

Processing and Utilization

One way of catalyzing pigeonpea production is to broaden the utilization base. This can be achieved by promoting the use of dehulled pigeonpea, which cooks quickly, is easy to digest and more palatable, and can be used to prepare a number of dishes. We intend to conduct a number of studies after Kenyan scientists have attended a training course on processing and utilization at IAC, India.

Budget

The budget for these studies will be determined after the training course at IAC.

Staffing

NARS	ICRISAT
P A Omanga - Breeder	S N Silim - Agronomist
G Kamau - Agronomist	S B King - Pathologist
P M Kimani - Breeder	E M Minja - Entomologist
W Songa - Pathologist	ICRISAT Socioeconomist
J M Songa - Entomologist	S Tuwafe - Breeder
B Bugusu - Food scientist	
P Audi - Socioeconomist	

Kenya Workplan Budget Summary

	Funding (US$) by Project
On-farm research	2800
Seed multiplication	1300
Multilocational trials	700
Screening for wilt and leaf spot resistance	700
Development of regional wilt nursery	500
Monitoring seasonal distribution of major pests	*
Processing and utilization	*
Total	**6000**

	Expected contribution from NARS (US$)
Emoluments	32400
Transport and vehicle maintenance	3000
Top-up fuel	2000
Office supplies	1500
Land and tractor use	1000
Farm inputs	1500
Total	**41400**

* To be decided later

Malawi—Collaborative Research Workplan

The pigeonpea collaborative research workplan for Malawi covers the following aspects:

- On-farm research and demonstrations
- Seed multiplication
- Back-up research (breeding, agronomy, and crop protection)
- Postharvest and processing studies
- Human resource development

On-farm Research and Demonstrations

Justification and objectives

Pigeonpea grain yields on farmers' fields in Malawi are low, partly because the long-duration landraces suffer from intermittent and terminal drought stress. Until recently, crop improvement research was directed largely at long-duration pigeonpea, although most of the crop is grown mainly in areas with short rainfall duration. To rectify this anomaly, we began introducing, testing, and selecting short-duration cultivars that would fit better into a more favorable moisture regime. Medium-duration lines were also tested. We have identified high-yielding, short- and medium-duration cultivars with acceptable pod and grain characteristics. These now need to be tested on farmers' fields. The on-farm trial aims at:

- Comparing the performance of the new short- and medium-duration varieties with long-duration landraces
- Providing farmers a diverse choice of cultivars from different maturity groups
- Setting up demonstration plots at strategic locations for farmers who did not participate in on-farm trials
- Eliciting farmers' perceptions of the varieties being tested
- Determining the potential and subsequently monitoring adoption of the new varieties.

Methodology

Genotypes. Three short-duration (ICPLs 151, 86012, 87105) and two medium-duration (QP 38, Royes) cultivars.

Locations. Four sites in each of the following Agricultural Development Divisions (ADDs); Shire Valley, Blantyre, Machinga, Lilongwe, Salima, Kasungu, Mzuzu, and Karonga.

Design. Randomized block with four replications. Spacing: short-duration, 90 cm ridges, 2 rows ridge^{-1}, 30 x 20 cm; medium-duration, 90 x 30 cm. Plot size 5.4 x 10 m.

Pest control. Apply recommended pesticides at start of flowering; again 10-15 days later, and a third spray (if required) 10-15 days after the second application.

Data. Sowing date, phenology, grain yield, and farmers' reactions.

Expected outputs

- Farmers made aware of the new varieties and associated production packages
- Recommendations on variety release (s)
- Possible release and adoption of suitable varieties.

Budget

	Funding (US$) by	
	NARS	Project
Travel and allowances	3500	1600
Operational costs		
Chemicals and supplies	3000	600
Communication	500	100
Support to field staff	500	500
Total	**7500**	**2800**

Staffing

NARS	ICRISAT
H N Soko - Breeder	S Tuwafe - Breeder
A A likoswe - Agronomist	E M Minja - Entomologist
ADD Crop Officers	S N Silim - Agronomist

Seed Multiplication

Justification and objectives

Once improved cultivars have been identified, large quantities of seed should be available within the country for on-farm testing, demonstrations by extension staff, and most importantly, for distribution to farmers who wish to take up pigeonpea cultivation. Foundation seed may also be required by seed multiplication agencies.

Methodology

Genotypes. Bulking of one released long-duration cultivar, ICP 9145, and four pre-release cultivars; Royes (medium-duration) and ICPLs 151, 86012, and 87105 (short-duration).

Locations. Bvumbwe, Chitedze, and Mkondezi.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation		200
Labor (sowing, weeding, etc.)	1500	500
Travel	2000	
Chemicals and field supplies	3000	500
Total	**6500**	**1200**

Staffing

NARS	ICRISAT
H N Soko - Breeder	S Tuwafe - Breeder S N Silim - Agronomist

Back-up Research

Back-up research aims at alleviating the major production constraints. It involves varietal evaluation of long-, medium-, and short-duration lines, agronomy, and crop protection.

Varietal Evaluation Trials

Justification and objectives

Concerted research effort on pigeonpea varietal development is much more recent than for other crops (e.g., maize). The long-duration landraces grown by farmers have been giving low yields because of (among other reasons) terminal drought stress and susceptibility to pests and diseases. Collaborative research by the national program and ICRISAT has resulted in the identification and release of ICP 9145, a long-duration cultivar resistant to fusarium wilt. In some parts of the country, farmers do not grow pigeonpea, but instead graze cattle in their fields after the maize harvest. The research work aims at:

- Providing farmers with flexibility by developing high-yielding varieties of different maturity groups with desirable characters (medium to large seed size, white, cream or speckled seed color, short cooking time, etc.)
- Developing cultivars resistant/tolerant to the major biotic and abiotic constraints.

Methodology

Genotypes. Germplasm from ICRISAT, local collections from Malawi, and superior nurseries from the Regional Program will be evaluated. Superior genotypes will be selected and tested further.

Locations. Baka, Bolero, Chitala, Makoka, and Ngabu.

Expected outputs

- Identification of superior lines for on-farm testing
- Better understanding of the phenological responses of each maturity group at different locations
- Recommendation for on-farm trials of superior lines.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation	200	
Operational costs		
Labor	800	500
Chemicals	500	500
Supplies	100	100
Travel	1000	
Total	**2600**	**1100**

Staffing

NARS	ICRISAT
H N Soko - Breeder	S Tuwafe - Breeder
T Kapewa	S N Silim - Agronomist
A A Likoswe - Agronomist	

Pest Management

Justification and objectives

One reason for low pigeonpea yields is severe attack by field pests. The short-duration types that have high yield potentials and have shown promise in Malawi are particularly prone to attack. Pest losses have not been quantified and effective, economical control measures are yet to be devised. The overall objective is to formulate an economical integrated pest management strategy to reduce crop losses.

Methodology

Genotypes. ICPL 87105 (determinate), ICPL 86012 (determinate), and QP 38 (nondeterminate).

Treatments. Chemical pest control; no spray, 1 spray (at flowering), 2 sprays (at flowering and 10 days later), 3 sprays (at flowering, and 10 and 20 days later).

Locations. Bunda College.

Design. Randomized block with four replications. Five ridges, 6 m long.

Data. Sowing date, phenology, grain yield losses due to pests.

Expected outputs

- Development of insect pest control methods
- Increased pigeonpea productivity.

Budget

	Funding (US$) by	
	NARS	Project
Labor (sowing, weeding, spraying, etc.)	1500	200
Travel	1000	
Field inputs (chemicals, etc.)	600	250
Communication	1000	50
Total	**4100**	**500**

Staffing

NARS	ICRISAT
G K C Nyirenda - Entomologist	E M Minja - Entomologist
H N Soko - Breeder	S Tuwafe - Breeder

Screening for Resistance to Fusarium Wilt

Justification and objectives

Previous research has indicated that fusarium wilt is the major pigeonpea disease in Malawi. From the 1979/80 season onward, wilt incidence has increased, leading to a decline in pigeonpea area. We therefore introduced germplasm from ICRISAT, screened it for wilt resistance, and identified a long-duration line, ICP 9145, which now occupies over 20% of the pigeonpea area in the country. We need more wilt-resistant lines and are continuing to screen new lines to identify those that are not only wilt-resistant but also have superior traits.

Methodology

Genotypes. Germplasm and breeding lines.

Locations. Wilt sick plots at Bvumbwe and Bunda College.

Design. 4 m x 1 row in two replications.

Data. Days to emergence, flowering, and maturity; number of plants at emergence; and number of wilted plants after every 10 days.

Expected output

- Identification of lines resistant to fusarium wilt.

Budget

	Funding (US$) by	
	NARS	Project
Labor	500	300
Supplies	300	200
Total	**800**	**500**

Staffing

NARS	ICRISAT
A T Daudi - Pathologist	P Subrahmanyam - Pathologist
V W Saka-Pathologist	M V Reddy - Pathologist
	S Tuwafe - Breeder

Development of a Regional Fusarium Wilt Nursery

Justification and objectives

As earlier studies have indicated, pigeonpea cultivars that showed resistance to fusarium wilt at ICRISAT Asia Center (IAC) showed variability in wilt reaction when tested in the eastern and southern Africa region. There are probably pathogenicity differences in *Fusarium udum* in different environments. We have constituted a nursery consisting of genotypes with known reactions to the pathogen for testing, initially in Kenya, Malawi, Tanzania, and India, to determine whether race differentials exist in the wilt pathogen. Development of the nursery will enable us to more clearly understand pathogenic variability in F. *udum.*

Methodology

Genotypes. Improved lines from Kenya, Malawi, Tanzania, and India.

Locations. Kenya - Katumani and Kiboko, Malawi - 2 sites, Tanzania - 1 site, India -IAC.

Design. Plot size: 4 m x 1 row in two replications.

Data. Days to emergence, flowering, and maturity; number of plants at emergence; and number of wilted plants after every 10 days.

Expected outputs

- Information on pathogenic variability in F. *udum*
- Performance evaluation of improved lines in different regions.

Budget

	Funding (US$) by	
	NARS	Project
Labor	300	150
Supplies	200	200
Total	500	350

Staffing

NARS	ICRISAT
A T Daudi - Pathologist V W Saka - Pathologist	P Subrahmanyam - Pathologist M V Reddy - Pathologist S Tuwafe - Breeder

Screening for Resistance to Nematodes

Justification and objectives

In some parts of Malawi, pigeonpea is heavily infested with nematodes. In tobacco-growing areas, farmers are looking for a suitable nematode-tolerant crop for inclusion in the rotation. Some pigeonpea varieties are known to be resistant to nematodes. We intend to test and identify resistant lines for introduction in these areas.

Methodology

Genotypes. Germplasm and breeding lines.

Locations. Baka, Bvumbwe, Bunda College, Chitala, Makoka, and Ngabu.

Design. One row 6 m long, unreplicated.

Expected output

- Identification of nematode-resistant lines for release or use in the breeding program.

Budget

	Funding (US$) by	
	NARS	Project
Labor	500	200
Supplies	300	200
Total	800	400

Staffing

NARS	ICRISAT
A T Daudi - Pathologist	P Subrahmanyam - Pathologist
V W Saka - Pathologist	S Tuwafe - Breeder

On-farm Observation Trial on Pigeon pea/Cotton Intercropping

Justification and objectives

Pigeonpea is generally intercropped, most commonly with maize, and also with cassava, sorghum, and cotton. We have been testing the potential for intercropping pigeonpea with cotton for the last 3 years, and now plan to test this technology in farmers' fields.

Methodology

Genotypes. Two short-duration (ICPL 86012, ICPL 87105) and two long-duration lines (ICP 9145, ICP 2376).

Locations. Eight ADDs.

Design. Randomized block with four replications.

Budget

	Funding (US$) by	
	NARS	Project
Travel	500	300
Chemical, bags, other field inputs	300	300
Communication	100	
Total	**900**	**600**

Staffing

NARS	ICRISAT
A A Likoswe - Agronomist	S N Silim - Agronomist S Tuwafe - Breeder

Human Resource Development

There is a need to train researchers and technicians at various levels so as to acquire and update skills. The following training needs have been identified:

- Long term—two researchers (an entomologist and an agronomist) to MSc level
- Short term, at IAC—three courses on processing and utilization; and a course for technicians (3 participants)
- Local training courses on processing and utilization
- Regional course on pigeonpea production

Malawi Research Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
On-farm trials	7500	2800
Seed multiplication	6500	1200
Back-up research		
Varietal evaluation trials	2600	1100
Pest management	4100	500
Fusarium wilt resistance screening	800	500
Regional Wilt Nursery	500	350
Nematode resistance screening	800	400
Agronomy	900	600
Total	**23700**	**7450**

Uganda—Collaborative Research Workplan

The pigeonpea collaborative research workplan for Uganda covers the following aspects:

- On-farm research and demonstrations
- Seed multiplication
- Back-up research (breeding, agronomy, and crop protection)
- Postharvest and processing studies
- Human resource development.

On-farm Research and Demonstrations

Justification and objectives

Pigeonpea grain yields on farmers' fields in Uganda are low, usually 300-500 kg ha^{-1}, partly because the medium- and long-duration landraces used have low yield potentials, and partly because of poor agronomic practices and susceptibility to pests and diseases. Farmers have only a limited choice of varieties. We have identified high-yielding, short-duration cultivars with acceptable pod and grain characteristics. These varieties were tested on farmers' fields in 1994 and the results are being analyzed. In 1995, we intend to expand our work. The on-farm trial aims at:

- Comparing the new short-duration varieties with medium-duration landraces (Apio Elina and Agali)
- Setting up demonstration plots at strategic locations for farmers who did not participate in on-farm trials
- Providing farmers with a choice of varieties from different maturity groups
- Eliciting farmers' perceptions of the varieties being tested
- Determining the potential and subsequently monitoring adoption of the new varieties.

Methodology

Genotypes. Four promising short-duration cultivars: Kat 60/8 and ICPLs 86005, 87091, and 87109.

Locations. Six districts in northern Uganda (Apac, Arua, Gulu, Lira, Soroti (Kaberamaido), and Nebbi) for grain yield trials, and one district (Luwero) for vegetable pigeonpea. The participating farmers will include those who are already involved in the 1994 first rains trials.

Design. Randomized block with two replications. Spacing 50 x 20 cm, 2 plants $hill^{-1}$. Plot size 10 x 10 m.

Pest control. Apply recommended pesticides; at start of flowering, again 10-15 days later, and a third spray (if required) 10-15 days after the second application.

Data. Sowing date, phenology, grain yield, and farmers' reactions.

Expected outputs

- Farmers made aware of the new varieties and associated production packages
- Recommendations on variety release(s)
- Possible release of suitable varieties and their adoption by farmers.

Budget

	Funding (US$) by	
	NARS	Project
Travel and allowances	3500	1600
Operational costs		
Chemicals and supplies	500	600
Communication	100	100
Support to field staff	1540	500
Total	**5640**	**2800**

Staffing

NARS	ICRISAT	NGOs
T E E Areke - Breeder	S Tuwafe - Breeder	CARE
H Okurut-Akol - Entomologist	E M Minja - Entomologist	ADP
M S Nahdy - Postharvest entomologist	S B King - Pathologist	World Vision
J E Obuo - Agronomist	S N Silim - Agronomist	
M Ugen - Agronomist		
Extension staff		

Seed Multiplication

Justification and objectives

Once improved cultivars have been identified, large quantities of seed should be made available within the country for on-farm testing, demonstrations by extension staff, and most importantly, for distribution to farmers who wish to take up pigeon-pea cultivation.

Methodology

Genotypes. Bulking of pre-release cultivars; ICPL 87091, 86005, and 87109, and Kat 60/8, and of Apio Elena and Agali.

Locations. Serere Research Station, and Prison Farm in Loro or Ngetta.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation	200	200
Labor (sowing, weeding, etc.)	500	500
Fuel and travel	800	
Allowances	1000	
Incentives for field staff		
Chemicals and field supplies		600
Seed purchase		*
Total	**2500**	**1300**

* No specific allocation; however, if seed multiplication by NARS is not possible, the funds will be used to purchase seed from private growers.

Staffing

NARS	ICRISAT
T E E Areke - Breeder	S N Silim - Agronomist
H Okurut-Akol - Entomologist	S Tuwafe - Breeder

Back-up Research

Back-up research under the Project aims at alleviating the major production constraints. Several aspects are covered: varietal evaluation of long-, medium-, and short-duration lines, agronomy, and crop protection.

Varietal Evaluation Trials

Justification and objectives

Concerted research effort on varietal development started only recently, with the launching of the Pigeonpea Improvement Project. The landraces grown by farmers are poor yielders, because of their low yield potentials and/or susceptibility to pests and diseases. The research work aims at:

- Developing high-yielding varieties of different maturity groups with desirable characters (medium to large seed size, white, cream or speckled seed color, short cooking time, etc.)
- Developing cultivars resistant/tolerant to the major abiotic and biotic constraints.

Methodology

Genotypes. Germplasm from ICRISAT, local collections from Uganda, and superior nurseries from the Regional Program will be evaluated. Superior lines will be selected from among these, and tested further.

Locations. Serere and Ngetta.

Expected outputs

- Identification of superior lines
- Better understanding of the phenological responses of each maturity group at different locations
- Recommendations for on-farm trials of superior lines.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation	200	
Operational costs		
Labor	800	500
Chemicals	300	500
Supplies	300	100
Allowances	1000	
Total	**2600**	**1100**

Staffing

NARS	ICRISAT
T E E Areke-Breeder	S Tuwafe - Breeder
H Okurut-Akol - Entomologist	E M Minja - Entomologist
J P Esele - Pathologist	S B King - Pathologist
	S N Silim - Agronomist

Agronomy

Justification and objectives

One reason for the low pigeonpea yields (300-500 kg ha^{-1}) in Uganda is that farmers use poor agronomic practices. The Project has been testing mainly introduced lines from different maturity groups, and high-yielding, short-duration cultivars with acceptable pod and grain characteristics have been identified. The agronomy trial aims at developing improved production practices for newly introduced short-duration lines and for landraces that are currently broadcast as a mixed crop with finger millet.

Methodology

The following experiments will be conducted at two locations, Ngetta and Serere.

- Optimum density trial—to determine optimum densities for different maturity groups
- Pigeonpea-millet intercropping—to develop optimal intercropping combinations of medium-duration pigeonpea with millet; millet will be broadcast and pigeonpea row-cropped
- Pigeonpea-groundnut intercropping—to develop optimal intercropping combinations of medium- and long-duration pigeonpea with groundnut; various row spacings will be tested.

Demonstration plots of the most suitable intercropping system will be sown on farmers' fields.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation	200	
Labor (sowing, weeding, etc.)	900	350
Travel	1000	200
Allowances	1000	
Incentives for field staff	200	
Materials and supplies	390	400
Total	**3690**	**950**

Staffing

NARS	ICRISAT
J E Obuo - Agronomist	S N Silim - Agronomist
H Okurut-Akol - Entomologist	
M S Nahdy - Postharvest technologist	

Pest Management

Justification and objectives

Pigeonpea, particularly the short-duration varieties, is severely attacked by field pests. Pest-related losses have not been quantified, and neither are the seasonality and distribution of pests and diseases known. The occurrence and distribution of fusarium wilt, a major disease of pigeonpea, has not yet been ascertained. The overall objective is formulate an integrated pest management strategy to reduce crop losses. The following studies will be carried out:

- Range, distribution, and seasonality of pigeonpea pests
- Screening cultivars for resistance to field pests in Ngetta and Serere
- Crop loss assessment
- Comparing the efficacy of natural products (e.g., neem and *Tephrosia)* with that of insecticide sprays (e.g., Salute®) under different spray regimes
- Economic evaluation of these spray regimes.

Budget[1]

	Funding (US$) by	
	NARS	Project
Land preparation	200	
Labor (sowing, weeding, spraying, etc.)	1000	200
Fuel (travel)	1000	
Allowances	1000	
Allowances for field staff	200	
Materials and supplies	390	300
Total	3790	500

1. For crop loss assessment and comparison of natural products vs insecticide sprays only. Other entomology studies will be conducted when funds are available.

Staffing

NARS	ICRISAT
H Okurut-Akol- Entomologist	E M Minja - Entomologist
M S Nahdy - Entomologist	

Postharvest and Processing—Socioeconomics

The objective is to understand the socioeconomic factors that influence pigeonpea production and acceptability in Uganda. This will be done through household surveys, marketing surveys, and follow-up surveys. This activity was planned for 1993/94, but was not taken up because of lack of funds. NARS funds have now been made available for 1994/95.

Budget

	Funding (US$)[1]
Fuel (travel)	500
Allowances	2000
Allowances for field staff	200
Total	2700

1. Funded entirely by NARS

Staffing

NARS	ICRISAT
T E E Areke - Breeder	S N Silim - Agronomist
H Okurut-Akol - Entomologist	
M S Nahdy - Postharvest entomologist	
J E Obuo - Agronomist	
Socioeconomist - to be identified in survey areas	

Postharvest Systems

Justification and objectives

The first broad objective is to improve availability and market value of pigeonpea by reducing postharvest losses, and thus improving food security, especially among resource-poor smallholder farmers. This will be addressed through:

- Screening for resistance to field infestation by storage pests, and seed resistance in storage
- Investigating and formulating control strategies involving solar disinfestation, biorationals, oils, etc. specifically to control storage pests
- On-farm trials on viable management options.

The second broad objective is to add value, increase utilization, improve marketing, and reduce labor bottlenecks, through appropriate processing techniques. This will be done by:

- Developing processing technologies for rural-based dehulling and medium-sized processors
- Evaluating technologies.

Budget

	Funding (US$) by	
	NARS	Project
Salaries and incentives	12000	-
Travel and allowances	800	400
Transport and vehicle maintenance	1200	-
Top-up fuel	600	-
Office and staff accommodation	1500	-
Land and tractor use, land preparation, other field-related activities	100	-
Utilities	150	-
Materials and supplies	100	300
Field and laboratory supplies (processing)	*	*
Total	**16450**	**700**

* Will be determined after the processing and utilization training course at ICRISAT Asia Center.

Human Resource Development

There is a need to train researchers and technicians at various levels so as to acquire and/or update skills. The following training needs have been identified:

- Long term: PhD training for an entomologist and an agronomist
- Short term: three processing and utilization training courses at IAC
- Local training courses on processing and utilization
- Regional training course on pigeonpea production
- Local training in computer skills.

Uganda Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
On-farm trials	5640	2800
Seed multiplication	2500	1300
Back-up research		
Varietal evaluation trials	2600	1100
Agronomy	3690	950
Pest management	3790	500
Postharvest studies		
Postharvest and processing: socioeconomics	2700	-
Postharvest systems	16450	700
Total	**37370**	**7350**

Tanzania—Collaborative Research Workplan

The collaborative research workplan for Tanzania covers five broad areas:

- On-farm trials
- Seed multiplication
- Back-up research
- Survey of fusarium wilt and production/marketing systems
- Processing studies.

On-farm Trials

Justification and objectives

Until recently, the most common cropping system with pigeonpea involved only medium- and long-duration landrace varieties. The Pigeonpea Project has identified short-duration lines that mature within 120 days, thus permitting the crop to be fitted into a more favorable moisture regime, and in some areas, for two crops to be grown each year. These are high-yielding varieties with acceptable pod and grain characteristics. The on-farm trial aims at:

- Evaluating the performance of the new varieties in farmers' fields
- Eliciting farmers' perceptions about these varieties
- Determining the potential and subsequently monitoring adoption of the new varieties.

Methodology

Genotypes. Four promising short-duration cultivars will be tested; ICPLs 86005, 87091, 87109, and 87 W.

Locations. Fifteen sites (15 farmers in Kilosa).

Design. Randomized block with two replications. Spacing 50 x 20 cm, 2 plants $hill^{-1}$. Plot size 10 x 10 m.

Pest control. Apply recommended pesticides; at start of flowering, again 10-15 days later, and a third spray (if required) 10-15 days after the second application.

Data. Sowing date, phenology, grain yield, and farmers' reactions.

Expected outputs

- Farmers made aware of the new varieties and associated production packages

- Recommendations on variety release(s)
- Possible release of suitable varieties.

Budget

	Funding (US$) by	
	NARS	Project
Travel and allowances	1150	760
Operational costs		
Field inputs	300	200
Labor	200	200
Reports and publications	150	100
Communication	100	40
Total	**1900**	**1300**

Seed Multiplication

Justification and objectives

One of the major constraints to the spread of released cultivars in the region is lack of seed. Experience with other crops has shown that once on-farm testing of promising new varieties begins, there is considerable demand for seed. The aim of this work is to a multiply seed of the most promising cultivars and make it available to farmers.

Methodology

The lines that show most promise in on-farm trials will be grown in irrigated plots protected from pests. Plot sizes will be 0.2-0.5 ha for each variety. In addition, seed of lines that will be tested in multilocational trials will also be increased.

Budget

	Funding (US$) by	
	NARS	Project
Land preparation	150	100
Labor	450	200
Chemicals	200	300
Supplies	150	150
Communication and travel	50	50
Total	**1000**	**800**

Back-up Research

Back-up research involves varietal evaluation of long-, medium-, and short-duration pigeonpeas; development of production packages (trials on sowing dates, spacing, and cropping systems); and screening for wilt resistance.

Varietal Evaluation Trials

In Tanzania, research on pigeonpea is recent, and no varieties have so far been released. Results from earlier work by ICRISAT Kenya indicate that pigeonpeas, particularly the long-duration varieties, have specific adaptation. The varieties currently available are poor yielders, probably because of low yield potentials or because they are not suitable for the areas where they are grown. The aim of these trials is to evaluate newly developed short-, medium-, and long-duration lines for adaptation and yield in different agroecological zones. Three trials are planned:

- Short-duration regional adaptation trial
- Medium-duration trial
- High-altitude long-duration multilocational trial.

Short-duration Regional Adaptation Trial

Methodology

Genotypes. Eighteen genotypes.

Locations. Ilonga (short and main rains), Mlingano (short and main rains), Ismani, and Naliendele.

Design. Randomized complete block with three replications. Plot size: four rows 4 m long. Spacing 50 x 20 cm, 2 plants hill*^{1}.

Data. Sowing dates, phenology, yield, and weather data.

Expected outputs

- Superior lines identified and recommended for on-farm testing
- Better understanding of phenological responses at different locations.

Medium-duration Pigeonpea Trial

Methodology

Genotypes. Eighteen genotypes.

Locations. Ilonga, Mlingano, and Naliendele.

Design. Randomized complete block with three replications. Plot size: four rows 4 m long. Spacing 75 x 40 cm.

Data. Sowing dates, phenology, yield, and weather data.

Expected outputs

- Superior lines identified and recommended for on-farm testing
- Better understanding of phenological responses at different locations.

High-altitude Long-duration Multilocational Trial

Methodology

Genotypes. Ten genotypes.

Locations. Two sites at Babati.

Design. Randomized complete block with three replications. Plot size: four rows 5 m long. Spacing 100 x 50 cm.

Data. Sowing dates, phenology, yield, and weather data.

Expected outputs

- Superior lines identified for on-farm testing
- Better understanding of phenological responses at different locations
- Recommendations for release of superior lines.

Budget for varietal evaluation trials

	Funding (US$) by	
	NARS	Project
Travel	560	360
Operational costs		
Field inputs	470	300
Labor	2016	1130
Field supplies	244	130
Office supplies	208	120
Communication	204	30
Reports and publications	366	130
Total	**4068**	**2200**

Development of Agronomy Packages

Agronomy research aims at developing production packages that will improve productivity and/or yield stability at farm level. Three agronomy studies are planned for the 1994/95 season:

- Effect of sowing date on yield and pest damage in short-duration pigeonpea
- Response of short-duration pigeonpea to spacing in different environments
- A new cropping system for short-duration pigeonpea.

Effect of Sowing Date on Yield and Pest Damage in Short-duration Pigeonpea

Results in eastern and southern Africa indicate that there is greater pest damage on short-duration than on long-duration pigeonpea, probably because temperatures, and therefore pest populations, are high during the reproductive phase of short-duration cultivars. One possible solution would be to delay sowing so that the reproductive phase coincides with the period of low temperatures and low insect populations. However, the yield penalty incurred because of late sowing is not known. The study aims to determine:

- The change in pest damage levels due to delayed sowing
- The extent to which delayed sowing reduces yield.

Methodology

Treatments. Genotype x date of sowing x pest control. Four sowing dates—Nov/Dec, and three further sowings at 14-day intervals with the onset of the long rains. Pest control by chemical sprays.

Genotype. ICPL 87 or ICPL 86005.

Locations. Ilonga (low altitude) and Gairo (medium altitude).

Design. Randomized complete block, 2 x 3 factorial.

Expected outputs

- Important pigeonpea pests identified
- Damage levels determined
- Recommendations on appropriate sowing dates.

Budget

	Funding (US$) by	
	NARS	Project
Travel	90	60
Operations		
Field inputs	138	140
Labor	96	60
Laboratory supplies	36	20
Communications	6	-
Reports and publications	24	20
Total	**390**	**300**

Response of Short-duration Pigeonpea to Spacing in Different Environments

Justification and objectives

Although promising short-duration lines have been identified, a production package for pigeonpea is yet to be developed. For example, appropriate population density is not known. This study aims to determine the appropriate seeding density for areas varying in moisture supply.

Methodology

Treatments. Row spacing x within-row spacing x plants hill-^{1}. Row spacing 40, 50, and 60 cm. Within-row spacing 20, 30, and 40 cm. Plants hill^{-1}:1 and 2.

Genotype. ICPL 87 or ICPL 86005.

Locations. Ilonga (wet, 500 m altitude), Gairo (moderately wet, 1000 m), and Hombolo (dry, 1037 m).

Design. Randomized complete block, 2 x 3 factorial.

Budget

	Funding (US$) by	
	NARS	Project
Travel	135	90
Operational costs		
Field inputs	207	140
Labor	144	110
Laboratory supplies	54	30
Communication	9	10
Reports and publications	36	20
Total	**585**	**400**

A New Cropping System for Short-duration Pigeonpea

Justification and objectives

In Tanzania, long-duration pigeonpea landraces are intercropped with maize or sorghum. In some of these areas, cereals are also intercropped with short-duration legumes (cowpea, beans, and green gram). Short-duration pigeonpea is being introduced into this cropping system as a potential supplement to other legumes. For such an introduction to be successful, trials need to be conducted to determine the most appropriate intercropping pattern.

Methodology

Design. Randomized complete block with four replications.

Treatments. Five treatments as shown below. In addition, the trial will include unreplicated plots of sole maize.

Treatment	Short rains	Long rains
T1	Pigeonpea/cowpea	Ratoon pigeonpea/cowpea
T2	Pigeonpea/cowpea	Ratoon pigeonpea/maize
T3	Pigeonpea/cowpea	Ratoon pigeonpea/cotton
T4	Pigeonpea/short-duration maize	Ratoon pigeonpea/full-season maize
T5	Pigeonpea/short-duration maize	Ratoon pigeonpea/cotton

Budget

	Funding (US$) by	
	NARS	Project
Travel	30	-
Operational costs		
Field inputs	69	50
Labor	48	40
Laboratory supplies	18	10
Communication	3	-
Reports and publications	12	10
Total	**180**	**110**

Screening for Resistance to Fusarium Wilt

Justification and objectives

Fusarium wilt is a major pigeonpea disease in Tanzania; incidence varies from 20% to 100% in farmers' fields. It is therefore critical to screen and identify lines resistant to the disease. The objectives of the study are to:

- Identify tolerant/resistant lines
- Determine whether these lines have acceptable agronomic characters
- Test superior lines on-farm.

Methodology

Germplasm and the wilt-resistant line ICP 9145 will be sown in a wilt sick plot.

Budget

	Funding (US$) by	
	NARS	Project
Operational costs		
Field inputs	30	40
Labor	200	100
Laboratory supplies	20	140
Communication		50
Reports and publications	12	10
Total	**262**	**340**

Survey of Fusarium Wilt and Production/Marketing Systems

Justification and objectives

Pigeonpea research in Tanzania is hampered by lack of information on several important aspects: the extent and distribution of fusarium wilt, production figures, and where pigeonpea is sold and how it is processed. The Project aims at surveying the major production areas in northern and southern Tanzania to collect this information, which will provide a database for research and for impact analysis.

Methodology

A multidisciplinary team of scientists and extension specialists will conduct the survey in the major pigeonpea-growing areas of Tanzania (Mtwara, Lindi, and Babati). The team will comprise four people: a breeder, pathologist, extension specialist, and agronomist/economist.

Expected outputs

- Information on the distribution and intensity of fusarium wilt in Tanzania
- A database that will be useful in setting research priorities.

Budget

The budget for these surveys is US$ 2000, to be provided entirely by the Project. NARS will provide transport.

Processing of Pigeonpea

This study will comprise three aspects:

- Processing of vegetable pigeonpea
- Demonstrations on processing pigeonpea grain into *dhal*
- Studies on cooking time for various varieties.

Budget

The budget for these studies is US$ 200, to be provided by the Project, supplemented by NARS funding of US$ 350.

Processing of Vegetable Pigeonpea

Justification and objectives

Although vegetable pigeonpea is popular in Tanzania, it can be used only when fresh because processing facilities are lacking. Green peas (vegetable pigeonpea) are available only for short periods. It is therefore necessary to develop a simple technology, especially for use in rural areas, for increasing shelf life by processing green peas.

Methodology

Treatments. Three dehydration treatments: blanched and dehydrated in the sun, blanched and dehydrated in a covered shed, blanched and dehydrated under a solar 'drier' (polyethylene sheet placed in the open).

Locations. Ilonga.

Demonstrations—Processing Pigeonpea Grain into *Dhal*

Justification and objectives

Whole-grain pigeonpea is susceptible to damage by insect pests in storage; it also takes relatively long to cook. When dehulled, pigeonpea cooks quickly and stores well. The Project aims both at improving the storability of pigeonpea and promoting its utilization as *dhal.*

Methodology

Two dehulling methods will be studied: using a grinding stone, and using an improved dehulling machine.

Locations. Kilosa, Babati, Morogoro Rural, and Mtwara.

Expected outputs

- Improved farmer awareness
- Better storability
- Reduced cooking time
- Increased palatability.

Cooking Time for Different Varieties

Justification and objectives

Dry pigeonpea grain takes a long time to cook. The study aims to identify variability among genotypes in cooking time of whole grain. Such variability, if it is found, will be used in the breeding program.

Methodology

Treatments. Duration of cooking: 30, 45, 60, 75, and 90 min using a Matson cooker.

Location. Sokoine University of Agriculture.

Staffing

NARS	ICRISAT
J K Mligo - Breeder	S N Silim - Agronomist
F A Myaka - Agronomist	S Tuwafe - Breeder
A M Mbwaga - Pathologist	E M Minja - Entomologist
A Chilagane - Farming Systems Research and Extension specialist	P Subrahmanyam - Pathologist
S T P Kundi - Food technologist	

Tanzania Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
On-farm trials	1900	1300
Seed multiplication	1000	800
Back-up research		
Varietal evaluation trials	4068	2200
Sowing date trial	390	300
Spacing trial	585	400
Cropping systems trial	180	110
Screening for wilt tolerance	262	340
Survey of fusarium wilt and production/ marketing systems[1]		2000
Processing studies	350	200
Total	**8735**	**7650**

1. NARS to provide a vehicle and fuel

Sudan—Collaborative Research Workplan

The collaborative research workplan for Sudan covers the following areas:

- On-farm evaluation of promising short- and medium-duration pigeonpea lines identified for irrigated and rainfed cropping systems
- Demonstration/seed multiplication
- Back-up research (varietal trials, agronomy)
- Postharvest technologies
- Field days.

On-farm Evaluation

Justification and objectives

We have identified some short- and medium-duration cultivars during trials in irrigated and rainfed cropping systems. We now need to evaluate these cultivars in farmers' fields in order to determine their potential and obtain feedback from farmers. The study has two components: on-farm trials and frontline demonstrations.

On-farm researcher-managed trial

Genotypes. Four promising varieties will be evaluated, with landraces as controls.

Locations. Irrigated areas—Gezira and New Haifa. Rainfed areas—El-Obeid, Gedarif, and Damazin. The number of sites will depend on 1993/94 results. At each location, 6-8 farmers will participate in the trials; each farmer will represent one replication.

Frontline demonstration

Large demonstration plots will be sown in the Gezira and Kordofan areas to acquaint farmers with the crop and our new promising varieties. Not more than two varieties will be used in this study.

Expected outputs

- Farmers made aware of the new varieties
- Recommendations on variety release (s)
- Feedback from farmers.

Budget

	Funding (US$) by Project[1]
Travel and allowances	1200
Chemicals, records	600
Communication and support to extension	300
Total	**2100**

1.NARS funding US$300.

Seed Multiplication

Justification and objectives

In order to promote the spread of improved pigeonpea varieties, large quantities of high-quality seed are required.

Methodology

Genotypes. Bulking of pre-release cultivars; Kat 787 and ICPLs 151, 87 W, and 87 B.

Locations. Gezira Research Station.

Design. More than 25 cultivars will be sown for increase. Plot size 0.25 ha for each variety.

Expected outputs

- 500-1000 kg of each pre-release variety
- 10-20 kg of each elite line.

Budget

	Funding (US$) by Project[1]
Operations	
Land preparation	100
Labor	400
Supplies	200
Total	**700**

1. NARS funding US$ 200

Back-up Research

Back-up research involves the following:

- Varietal evaluation
- Cropping systems studies
- Population density studies.

Justification and objectives

We have now intensified our research on pigeonpea improvement. Before the Pigeonpea Improvement Project was launched, only unimproved medium-duration landraces were grown in Sudan. Since 1992, we have introduced material from all duration groups and identified promising short- and medium-duration cultivars. We will continue to introduce and test new lines, but need to develop agronomy packages for both irrigated and rainfed conditions to ensure the spread of pigeonpea. Our main thrust is to increase the area under pigeonpea in both irrigated (Gezira and New Haifa) and rainfed areas (Western and Eastern Sudan).

Varietal Evaluation

Methodology

The trials will include both short- and medium-duration varieties. Varieties will be evaluated for phenology, yield, and yield components including biomass.

Expected output

- Promising high-yielding cultivars identified for on-farm trials and eventual release.

Budget

	Funding (US$) by Project[1]
Travel	100
Operational costs	
Field inputs	200
Labor	200
Communication and supplies	100
Total	**600**

1. NARS funding US$ 1000.

Agronomy

Agronomy trials aim at developing appropriate packages for sole and intercropping pigeonpea systems.

Budget

	Funding (US$) by Project[1]
Travel	150
Operational costs	
Field inputs	200
Labor	200
Office supplies and communication	50
Total	**600**

1. NARS funding US$ 1000.

Postharvest Technologies

These studies will cover the following aspects:

- Storage and handling
- Processing and utilization.

Expected outputs

- Recommendations on appropriate storage methods and processing/utilization techniques.

Budget

The Project budget for postharvest studies will be developed after the training course on processing and utilization at IAC. The Sudan NARS has budgeted US$ 500 for this activity.

Staffing

NARS	ICRISAT
Hassan O El Awad	S N Silim - Agronomist
Abdel Rahman K Osman	S Tuwafe - Breeder
Mohammed M Balala	E M Minja - Entomologist
M A M Khair	
Mirghani Saeed	
Ibrahim Nureldin	
Musa Babiker	

Sudan Collaborative Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
On-farm research	300	2100
Seed multiplication	200	700
Back-up research		
Varietal evaluation	1000	600
Agronomy	1000	600
Postharvest technology	500	*
Total	**3000**	**4000**

* will be finalized after the training course at IAC

Zambia—Collaborative Research Workplan

The pigeonpea collaborative research workplan for Zambia covers the following aspects:

- On farm research (on-going)
- Seed multiplication (new)
- Back-up research (on breeding, on-going)
- Human resource development.

On-farm Research

Justification and objectives

The Food Legumes Research Team in Zambia has been testing, on farmers' fields, medium-duration varieties identified from previous on-station varietal evaluation. We have also been testing short-duration cultivars on-station, and have identified superior lines. In the 1994/95 season, four short-duration genotypes will be included in on-farm trials in order to evaluate their performance and obtain farmers' assessments of their suitability. The on-farm trial aims at:

- Evaluating the performance of the new short- and medium-duration varieties on farmers' fields
- Providing farmers with a diverse choice of varieties from different maturity groups
- Eliciting farmers' perceptions of the varieties being tested
- Determining the potential and subsequently monitoring adoption of the new varieties.

Methodology

Genotypes. Four short-duration (ICPLs 84023, 86015, 88009, 90044) and four medium-duration (ICP 7035, HY 3C, 423/50/3, WPP 670) cultivars.

Locations. Eastern Province

Design. Randomized block with two replications. Spacing 45 x 10 cm for short-duration and 90 x 30 cm for medium-duration cultivars. Plot size 5.4 x 10 m.

Pest control. Apply recommended pesticides at start of flowering, again 10-15 days later, and a third spray (if required) 10-15 days after the second application.

Data. Sowing date, phenology, grain yield, and farmers' reactions.

Expected outputs

- Farmers made aware of the new varieties and associated production packages
- Recommendations on variety release (s)
- Possible release of suitable varieties.

Budget

	Funding (US$) by	
	NARS	Project
Travel and allowances	400	700
Operational costs		
Chemicals and supplies	2700	700
Communication and supplies		100
Total	**3100**	**1500**

Seed Multiplication

Justification and objectives

One of the major constraints to the spread of newly released varieties is the availability of quality seed in large quantities. We have identified pigeonpea varieties, and these are currently being tested in farmers' fields; seed is now required for distribution to farmers for cultivation. This activity will not require financial support from the Regional Project. However, the national program requires pure stocks of seed, 5 kg each, of the following cultivars for multiplication: ICP 7035, 423/50/3, HY 3C, WPP 670, and ICPLs 84023, 86015, 88009, and 90044. NARS funding for seed multiplication has been budgeted at US$ 3000.

Back-up Research—Varietal Development

Concerted research effort on pigeonpea varietal development started recently, with the launching of the Pigeonpea Improvement Project. The research work aims at:

- Developing high-yielding varieties of different maturity groups with desirable characters (medium to large seed size, white, cream or speckled seed color, short cooking time, etc.)
- Developing cultivars that are resistant/tolerant to the major biotic and abiotic constraints.

Methodology

Genotypes. Short-, medium-, and long-duration genotypes.

Locations. Three locations.

Expected outputs

- Identification and recommendation of superior lines for on-farm testing
- Better understanding of the phenological responses of each maturity group at different locations.

Budget

	Funding (US$) by	
	NARS	Project
Travel	500	200
Operational costs		
Labor	800	300
Chemicals	400	300
Supplies	500	100
Total	**2200**	**900**

Human Resource Development

The immediate training needs for Zambia have been identified; they include:

- Long-term training: PhD in agronomy
- Short-term training (at ICRISAT Asia Center): three training courses on processing and utilization; a technicians' course for two people
- Local training courses on processing and utilization
- Regional course on pigeonpea production.

Staffing

NARS	ICRISAT
K Kanenga - Agronomist	S Tuwafe - Breeder
J Mulila-Mitti - Breeder	S N Silim - Agronomist
P H Sohati - Entomologist	P Subrahmanyam - Pathologist
R Raussen - Agronomist (Farming Systems Research)	E M Minja - Entomologist
K MuiMui - Breeder	
Extension staff	

Zambia Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
On-farm trials	3100	1500
Seed multiplication	3000	
Back-up research		
Varietal evaluation trials	2200	900
Total	**8300**	**2400**

The Food and Agriculture Organization (FAO) and the United Nations Development Programme (UNDP) are funding seed multiplication, seed multiplication training for farmers, and in-country training on processing and utilization.

Namibia—Collaborative Research Workplan

The pigeonpea collaborative research workplan for Namibia covers the following aspects:

- On-station varietal evaluation
- On-station demonstration/seed increase
- On-farm intercropping trials.

Justification and objectives

The main crops grown in Namibia are pearl millet and sorghum, and maize on a smaller scale. The legumes grown are mainly cowpea, groundnut, and bambara nut. Pearl millet is sown in rows 1 m apart or broadcast, at low populations. Similar patterns are used for sorghum and maize. Groundnut and cowpea are normally mix-cropped or intercropped with cereals, or grown as sole crops. We believe that pigeon-pea would fit into the cereal-based cropping system as an intercrop without adversely affecting pearl millet yield. The soils are very sandy (80-95% sand) and leaching is a problem. Because of its deep roots, pigeonpea would obtain water and leached nutrients from the deeper soil layers, and through leaf fall, also make nutrients available to the cereal crops. The Project aims at:

- Evaluating the potential of pigeonpea in Namibia
- Testing and selecting adapted varieties
- Introducing pigeonpea to farmers as an alternative crop
- Growing pigeonpea under farmers' conditions to obtain farmers' impressions
- Sowing promising varieties on a large scale for demonstration, seed increase, and socioeconomic evaluation.

Expected outputs

- Acceptance of pigeonpea by farmers
- Identification of adapted varieties for on-farm testing and possible release.

On-station Varietal Evaluation

Methodology

Genotypes. Sets of short-, medium-, and long-duration lines from ICRISAT's Regional Pigeonpea Improvement Project.

Locations. Omahanene, Bagani, Uitkomst.

Design. Randomized block with four replications for short-duration, and three replications for medium- and long-duration lines. Plot size: 6 rows 8 m long. Spacing:

50 x 20 cm for short-duration, 100-125 x 50-75 cm for medium- and long-duration lines.

On-station Demonstration/Seed Increase

Methodology

Genotypes. Promising short-duration lines from ICRISAT's Regional Pigeonpea Improvement Project.

Locations. Omahanene and Bagani.

Design. Large plots will be sown at each location with 5 kg seed of each cultivar. Spacing 50 x 20 cm.

On-farm Intercropping Trial

Methodology

Genotypes. Medium-duration pigeonpea (ICP 6927) and the available pearl millet cultivar.

Locations. Omahanene, Bagani.

Design. Randomized block with three replications.

Treatments. Five treatments—sole millet, sole pigeonpea (1 x 1 m), sole pigeonpea (1.5 x 1 m), millet-pigeonpea intercropped within rows, and millet-pigeonpea intercropped between rows.

A field day will be organized in Mar or Apr 1995.

Staffing and Visits

NARS	ICRISAT[1]
D J M Marais - Agronomist	S Tuwafe • Breeder S N Silim - Agronomist

1. We expect scientists from the ICRISAT Regional Project to visit Namibia at least twice, one visit being between Mar and Apr.

Namibia Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
Travel (in-country)	3000	
Field inputs		
Seed, tags, bags, etc.	500	
Labor	3000	
Field day		2000
Total	**6500**	**2000**

Lesotho—Collaborative Research Workplan

The collaborative research workplan for Lesotho covers two broad areas:

- On-farm pigeonpea evaluation
- On-station pigeonpea evaluation.

On-farm Evaluation

Justification and objectives

Pigeonpea is a new crop in the country. We intend to introduce it as a summer crop in the lowland zone, where crops are usually sown between 15 Oct and 15 Nov and harvested between Mar and May. Only short-duration varieties are likely to be suitable, and these will be evaluated under farmers' conditions for grain yield and potential to supply firewood.

Methodology

Genotypes. Three lines, ICPLs 86005, 86012, and 87105.

Locations. Four sites (farmers' fields) in Maseru district, possibly near Maseru Research Station.

Design. Randomized block with two replications. Spacing 40 x 10 cm. Plot size 10 x 9 m.

Pest control. Apply recommended pesticides; at start of flowering, 10-15 days later, and a third spray (if required) 10-15 days after the second application.

Data. Sowing date, phenology, grain yield, and farmers' reactions.

Expected outputs

- Introduction and identification of superior lines
- On-farm testing and evaluation of promising materials
- Recommendations for release(s), depending on results of on-farm testing
- Organization of seed multiplication schemes
- Adoption of pigeonpea and its use in cropping systems
- Development of processing and utilization methods.

Staffing

NARS	ICRISAT
S S Moima - Agronomist G N Makhale	S Tuwafe - Breeder S N Silim - Agronomist

Lesotho Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
Travel	200	100
Operational costs		
Field inputs	400	200
Labor	300	150
Reporting and publications	50	50
Total	**950**	**500**

Pigeonpea is a new crop in Swaziland, introduced during the 1993/94 season, when it was tested at three sites. The crop appears to be adapted to dry areas, where it was the only crop that remained green during winter (some varieties were still flowering and producing pods). Pigeonpea could, therefore, provide green pods for vegetable use and forage for livestock during the dry winter period. The collaborative research workplan for the country covers two broad areas:

- On-station evaluation
- On-farm evaluation.

Varietal Evaluation Trials

Justification and objectives

In Swaziland, pigeonpea research was initiated only after the Pigeonpea Improvement Project was launched. Till recently, few farmers were aware of the crop. However, pigeonpea has potential in the country because of its drought tolerance and its ability to contribute to sustainability; it can be grown for on-farm consumption or as a cash crop. We intend to introduce pigeonpea in dry areas of the country (500-800 mm annual rainfall, during Oct-Apr) for grain, firewood, fodder, and possibly for vegetable use as green peas.

The present farming system in this region is based predominantly on cotton and maize, which are both sown in Oct. Maize is harvested in Mar and cotton in Jul. Maize is mix-cropped with melons, cowpea, and pumpkins as minor components. Introducing a legume into the system will improve sustainability, farm family nutrition, and incomes. The objectives of the study are to:

- Introduce and test short-duration pigeonpeas in this environment for grain, fodder, and vegetable use
- Introduce and test ratoonable medium- and long-duration cultivars for food, fodder, and firewood use.

Long-duration Varietal Trial

The Project intends to introduce long-duration varieties in dry areas: Luve (dry Middleveld, 600 m altitude, rainfall 500 mm, sandy loam soils) and Big Bend (Lowveld, 300 m altitude, rainfall 350 mm, Vertisols). We plan to develop technologies at these sites, consolidated into a pigeonpea production package, in the near future.

Genotypes. ICRISAT's regional program will provide two sets of long-duration pigeonpea.

Locations. Luve and Big Bend.

Design. Randomized block with three replications. Plot size: four rows 6 m long. Spacing 90 x 40 cm.

Data. Sowing date, phenology, yield, and yield components.

Pest management. Two sprays: one at start of flowering, and the second 10-15 days later.

On-farm Trials

Justification and objectives

In 1993/94, short-duration varieties were tested at Malkerns (moist Middleveld, >600 mm rainfall) and Luve (dry Middleveld, 600 mm), while varieties from all three maturity groups were tested at Big Bend (Lowveld, 350 mm rainfall). Some very promising cultivars were identified as being suitable for dry areas. In the 1994/95 season, these varieties will be tested on farmers' fields jointly by farmers, researchers, and extension workers. The crop will be managed by farmers under the direct supervision of researchers and extension workers to ensure proper sowing, monitoring, and harvesting.

Methodology

Genotypes. Three medium/long-duration genotypes (ICP 9145, PGM 9208, QP 14), and three short-duration genotypes (ICPLs 86005, 86012, 90024).

Locations. Four areas with three farmers each. These will be selected jointly with extension workers.

Design. Three or four varieties will be sown on each farm. Plot size: 10 rows x 10 m long. Spacing: short-duration 45-60 x 10-20 cm; medium- and long-duration 90 x 50 cm and 2 plants $hill^{-1}$.

Data. Days to 50% flowering and maturity, plant height at harvest, grain and dry stalk yields, and farmers' reactions to varietal performance (reactions will be evaluated by socioeconomists). The two border rows will be used to assess green pod yield and use.

Pest management. Two sprays, the first at start of flowering, and the second 10-15 days later.

Field days will also be organized for farmers at these sites, and will include cooking demonstrations using both dry grain and green peas.

Training—Pigeonpea Production, Processing, and Utilization

Justification and objectives

Pigeonpea has considerable potential in Swaziland. However, it is important to train researchers and extension workers in production and utilization in order to promote the crop. The objectives of this study are to:

- Train food technologists in utilization and processing methods
- Train technicians and extension workers in production techniques.

Staffing

NARS	ICRISAT
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K Mabuza - Food technologist	S Tuwafe - Breeder
M Nsibande - Entomologist	
P Shongwe - Agricultural economist	
C Malima - Agronomist/Extension specialist	

Swaziland Workplan Budget Summary

	Funding (US$) by	
	NARS	Project
Travel (in-country)	700	400
Operational costs		
Field inputs	400	400
Field days	600	300
Seed-bed preparation	100	
Labor	1700	500
Total	**3500**	**1600**

Mozambique—Collaborative Research Workplan

Scientists from Mozambique did not attend the meeting.

Concluding Session

Highlights of Research Results, Workplans, and Recommendations

Regional Program Activities

Seed multiplication

About 2000 kg seed of Kat 60/8 and ICPLs 87091, 87109, and 87 W, together with small quantities of ICPLs 86005, 87101, 87104, 87105, 90013, 90028 and 90029, ICP 6927, Tanzania 9, Kat 81/3/3, and NPP 670 were produced by the ICRISAT Pigeonpea Project in Kenya, for regional use. About 1000 kg of seed has been distributed to the national programs.

About 600 kg seed of ICPLs 86102, 87105, 9145, and 87 was multiplied at the Pigeonpea Project Station in Malawi. In addition, 120 kg seed of 12 short-duration lines was produced for regional varietal trials.

Genetic enhancement

Fifty seven individual plants were selected for a multilocational observation nursery in the region. These selections were made on the basis of seed size (100-seed mass 11-18 g) and seed color (cream/white). Similarly, segregating populations were advanced using a modified bulk breeding method for selecting large, white seeds.

F_3 bulk populations of 15 single crosses were produced. These will be distributed in the region for further selection.

To incorporate wilt resistance, 30 crosses were made between the resistant line ICP 9145 and promising medium-, long-, and short-duration cultivars.

Stability analysis of 10 short-duration varieties was performed across 15 environments in 5 countries. Three lines (ICPLs 86012, 90028, and 90029) gave stable yields of over 1.5 t ha^{-1}.

Photothermal adaptation studies

In the short-duration group the optimal temperature range for rapid flowering was 19-24°C. Outside this range, flowering was delayed in short-duration genotypes. Reduction in temperature (at higher altitudes) reduced plant height, with ICPLs 9504, 87091, 87109, and 90001 showing relative stability in all environments. Seventeen cultivars were identified as having high yield potential and wide adaptation. Cultivars with specific adaptation to different altitudes were identified for low to medium altitude, medium altitude, and medium to high altitude areas.

The medium- and long-duration groups exhibited more specific adaptation to temperature variation. Long-duration cultivars had low optimal temperature (<18°C) for rapid flowering. The optimal temperature range for rapid flowering in medium-duration cultivars was 22-24° C, which is similar to that for the short-duration group.

The Kenya transect can effectively be used to screen a large number of cultivars and target the ones best adapted to different agroecological zones in the region.

Consultancies

Regional consultants were identified for entomology and processing and utilization. They participated in the Meeting, and interacted closely with the national scientists.

Human resource development

Four scientists who are supported by the Project, one each from Kenya, Malawi, Tanzania, and Uganda, are enrolled in PhD programs. Monitoring tours and in-service training were also conducted.

Country Highlights

Ongoing activities in each country in the region are summarized in Table 1. The highlights of 1993/94 research results from each participating country are given below.

Kenya

Multilocational trials. Multilocational varietal trials of medium-duration lines revealed stable and high yield potentials (1 t ha^{-1}) in Kat 60/8, KO 91, KO 237, and ICP 6927 across locations during the severe drought year (1993/94). In the short-duration group ICPLs 86005, 87091, 87105, and 87109 were the best yielders across locations (1.5-2.5 t ha^{-1}). Among the vegetable types, ICPL 87091, Tanz 9, Gujarat Local, ICP 7035, and Kat 60/8 gave the highest green pod yields (5-7 t ha^{-1}) at two locations.

On-farm trials. On-farm trials of short-duration pigeonpea were conducted in Eastern Province. Five varieties (Kat 60/8 and ICPLs 151, 87091, 87109, and 90028) gave yields of 0.5-0.7 t ha^{-1} on 10 farmers' fields during the year when most other crops failed. Two varieties, Kat 60/8 and ICPL 87091, were grown by farmers as vegetable pigeonpea in irrigation schemes involving women's groups and NGOs. One farmer earned a net income of over KSh 10 400 from a 0.5 ha plot, through the sale of green pods for export.

Table 1. Pigeonpea research in eastern and southern Africa: ongoing activities in each country.

Activity	Kenya	Malawi	Tanzania	Uganda	Lesotho	Namibia	Sudan	Swaziland	Zambia
On-farm research	+	+	+	+	+	+	+	+	+
Seed multiplication	+	+	+	+	+	+	+		+
Multilocational trials	+	+	+	+		+		+	
Wilt resistance	+	+	+	+					
Regional wilt nursery	+	+	+	+					
Pest survey	+		+	+					
Processing and utilization	+		+	+				+	
IDM/IPM	+	+		+					
Chemical pest control		+	+						
Nematodes		+							
Training	+	+	+	+				+	+
Demonstrations		+		+		+	+		+
Back-up research			+	+		+	+		+
Socioeconomics				+					
Postharvest studies				+			+		

Production package for short-duration pigeonpea. At the coastal site (Mombasa) and at Kiboko (Oct sowing), where temperatures were high, optimum sowing density was 222 222 plants ha^{-1}. At low-temperature sites, Kabete and Kiboko (Apr sowing), the optimum density was higher (285 714 plants ha^{-1}). Intercropping studies were conducted with maize and pigeonpea, to determine optimum spacing. The best results (maize yield close to that of sole maize, and a land equivalent ratio of 1.3) were obtained with two rows of short-duration pigeonpea with paired rows of maize (40 cm spacing).

Wilt and cercospora leaf spot. A new wilt sick plot was developed at Kiboko in addition to the one already available at Katumani. Wilt incidence in most lines was higher at Kiboko than at Katumani. For example, ICP 9145 showed resistance at Katumani but was susceptible at Kiboko. A wilt and cercospora leaf spot nursery was developed at Katumani for combined screening against both diseases.

The short-duration lines ICPLs 87104, 87105, and 90013 showed around 30% wilt at Kiboko. Medium-duration lines BDN 1 and ICPL 87091, in contrast, showed less than 10% wilt at Kiboko. At Katumani, eight introduced lines (ICP 8863, ICPL 89048, GPS 3, GPS 7, GPS 30, GPS 33, GPS 36, and GPS 52) and 13 improved lines (Kat 15/94,18/9, 20/94, 29/94, 59/94, 99/94,122/94,158/94, 217/94, 231/94, 248/94, 595/94, and 603/94) showed less than 10% wilt.

Malawi

On the basis of multilocational trials, two medium-duration lines (QP 38 and Royes) and three short-duration lines (ICPLs 151, 86012, and 87105) were advanced to on-farm trials in eight agricultural divisions.

Wilt incidence in Malawi was reduced from 36% in 1982 to 5.4% in 1993 after the release of ICP 9145 in 1987. Three hundred and twelve isolates of *Fusarium udum* were collected from soil and plant samples in Malawi, and showed differences in growth rate, growth pattern, pigmentation, and sporulation.

Preliminary observations indicate that ICPH 8, ICPL 151, and ICPL 87113 showed resistance to root knot nematodes at Bvumbwe Research Station in Malawi. ICPL 24 (long-duration) also showed resistance.

Tanzania

Multilocational trials. In a multilocational trial of short-duration varieties, ICPL 86005 and ICPL 90028 gave yields of 2 t ha^{*1} at Ilonga. The other promising varieties were Kat 60/8 and ICPLs 87, 86012, and 87101. Seed multiplication and on-farm testing of some varieties identified in previous evaluations (ICPLs 87, 86005, 86012, and 90028) has already begun.

In the medium-duration group, ICPL 87119 and ICPL 93002 produced 2 t ha^{-1} at Ilonga. Five other five promising lines (ICPL 87075, ICPL 87067, ICP 7035 W, Kat

60/8, and 50/3) identified from earlier evaluations are already under seed multiplication and on-farm testing.

Due to severe drought, most of the long-duration cultivars produced very low yields (<1 t ha^{-1}).

In the short-duration group, pest management remains a problem. Insect pressure (pod borer) was very high in trials at the Kilombero Agricultural Training and Research Institute (KATRIN), and pesticide use did not seem to be effective.

Production package for short-duration pigeonpea. At Ilonga (a wet environment), no significant effect of interrow spacing on grain yield was observed. However, at Hombolo (dry environment), yields were higher at narrow interrow spacing than at wide spacing. Within-row spacing was important at Ilonga, but not at Hombolo.

Significant yield reduction occurred when pigeonpea was sown later than 2 Mar. At lower temperatures pod borer damage was reduced, but damage due to pod-sucking bugs increased.

Short-duration pigeonpea performed better than sorghum in dry environments. A row ratio of 1:1 or 1:2 of pigeonpea:sorghum was more efficient than either sole crop or various other row ratios tested.

Fusarium wilt. A wilt sick plot was developed at Ilonga Research Station. ICP 9145 was found resistant to wilt (10% incidence) in the sick plot, and is a potential cultivar for southern Tanzania, where wilt is a serious problem. Four lines—HY 3C and PGMs 9208, 9233, and 9234—showed less than 20% wilt. All six short-duration lines received from ICRISAT were found susceptible. Out of nine medium-duration lines from ICRISAT, ICPL 270 (32% wilt incidence) and ICPL 38 (39%) showed promise.

Uganda

Yield/agronomy trials. In a short-duration varietal trial, ICPLs 87,151, 87091, and 90029 produced grain yields of over 2 t ha^{-1}. However, Kat 60/8, which is of later phenology, was severely affected by blister beetles. Other promising varieties with grain yields of 3-4 t ha^{-1} were Upas 120 and ICPL 90023. In the medium-duration group IPH 487 and ICPL 90003 were found promising (mean yields 3-4 t ha^{-1}).

A trial was conducted with ICPL 87091 and Kat 60/8 to determine optimum plant population. The best yields were obtained with a spacing of 30 x 10 cm.

On-farm trials. On-farm trials with Kat 60/8 and ICPLs 87, 86005, 87091, and 87109 are in progress. From 200 g of Kat 60/8 seed given to a farmer in Dec 1992, over 120 kg of seed was obtained, which has been sown by several farmers on over 4 ha.

Storage pests. Field spraying with 0.5% cypermethrin reduced field infestation of *Helicoverpa armigera* and *Callosobruchus chinensis.* Storage in the pod in reed baskets and the traditional straw-mud-cowdung silo were highly effective in controlling

C. *chinensis.* Leaves of *Tephrosia* sp and *Nicotiane tabacci* were also found to be effective in controlling storage pests.

Alternaria blight. Almost all the 1000 short- and medium-duration lines introduced from ICRISAT were wiped out by alternaria blight at Kawanda Agricultural Research Station, Kampala. The long-duration landraces did not suffer much from the disease.

Sudan

In an attempt to introduce the crop into the pearl millet based cropping system in a harsh, dry environment, two varieties (short-duration ICPL 87 and medium- to long-duration Kat 878) were tested on-farm. Kat 878 has the special characteristic of remaining green until Mar, and also appears to have drought resistance.

ICPL 151 and ICP 3869 have also been found promising. On the basis of trials in irrigated areas, ICPL 151 and ICPL 90028 were recommended for on-farm trials in view of their performances and their ability to fit into the crop rotation.

Zambia

Varietal trials. In short-duration varietal trials, the most promising varieties, with yields of 1.5-2.0 t ha^{-1}, were ICPLs 84023, 86015, 88009, 88030, and 90044. In the medium-duration group, four varieties were tested on-farm: 423/50/3, NPP 670, HY 3C, and ICP 7035. In the first season the crop was affected by insect pests. However, these varieties survived the severe drought and gave ratoon yields of 500 kg ha^{-1}; 423/50/3 in particular exhibited good ratoonability.

Seed multiplication. At the Golden Valley Research Station, 800 kg of ICP 7035 seed was obtained from seed multiplication. Requests for 700 kg have been received from the drier provinces.

Namibia

Medium- and long-duration lines gave fairly good yields, while the short-duration varieties tested gave poor yields due to heavy insect pest damage and low population.

The research emphasis will be on testing pigeonpea to improve the sustainability of millet-based farming systems, and on extension work to increase farmer acceptance of this new crop.

Swaziland

ICPL 86012 was identified as suitable for both dry and wet environments, with mean yields of 1.5 t ha^{-1}. Other promising varieties were ICPLs 86005, 90024, and 90029.

In the long-duration group, ICP 9145 and QP 14 were identified for further testing.

Lesotho

Short-duration (rather than medium-duration) cultivars are recommended, because of frequent droughts and the short growing season caused by early frost. Insect pests (CMR beetle) may also be a potential problem. Trials of short- and medium-duration varieties are in progress, and will continue in the 1994/95 season.

Other Issues Targeted by the Project

- Considerable emphasis is being placed on integration of the gender issue into research planning. In all the countries involved in this program, rural women are being involved in on-farm trials and demonstrations of new varieties, postharvest technology, and processing and utilization. The women are trained on processing and utilization methods and on crop production and management practices.
- Project activities are geared towards the sustainability of farming systems. The various benefits that pigeonpea can provide (in terms of improving soil fertility, reducing wind/soil erosion, as an agroforestry component, etc.) are being stressed both in research planning and in extension work.
- Future activities will involve closer linkages with the private sector. It is anticipated that the processing and utilization component will significantly increase marketing opportunities for pigeonpea farmers, and thus increase rural employment and incomes.

Workplans

Workplans and budgets were presented by the individual countries. It was recommended that the budgets be rationalized by the regional scientists based on regional priorities and the needs and opportunities in the various countries in the region. Four priority areas will be emphasized:

- On-farm trials (for transfer of technology)
- Seed multiplication
- Regional cooperation
- Training.

It was recommended that certain areas of research should be of a regional nature and be developed, executed, coordinated, and reported explicitly. These are:

- Regional drought screening nursery
- Regional wilt resistance and race identification nursery
- Seed multiplication
- Monitoring visits by national scientists to specific countries
- Monitoring tours during the crop season—these must be budgeted for and executed
- In-service training in the region in certain areas such as pest management, agroprocessing, and utilization — these would be part of the insect pest management and processing and utilization consultancies
- Equipment and utilization training for women's groups should also form a part of the consultants' programs
- An illustrated booklet on recipes and utilization of pigeonpea should published as soon as possible in English and local languages.

These programs will help remove regional imbalances in expertise and facilities.

Concluding Address

G M Mitawa[1]

Mr Chairman, ladies and gentlemen

Thank you for inviting me to present my views on how this meeting went. In a manner of speaking, I have been ambushed; I did not come prepared to make a speech, and I hope my extempore remarks will be viewed in light of that fact.

It has been a pleasure to be a part of this group, and of the process of planning our work for the next crop season. One aspect of the Pigeonpea Improvement Project is particularly striking. I have been involved, in various capacities, in a number of working groups and project planning committees. But this is one of the few projects that has a clear sense of direction and purpose. Workplans and budgets are discussed in detail; a consensus is arrived at; and most important, progress is reviewed after each season. With goals—and how to reach them—clearly laid out, it becomes much easier for a project to succeed. I think this is an example that other projects in the region would do well to follow.

Our work covers a large and diverse region, with a number of constraints. The only approach that is likely to be successful against this background is a cooperative one. We must work, as we have been doing in the past, on a regional basis, identifying strengths and weaknesses, sharing our resources efficiently so that expertise developed in one country can be used in another, and avoiding duplication of effort. And we must maintain our spirit of optimism.

There has been excellent NARS representation at the Meeting, ample proof of their commitment to pigeonpea in general and to the Project in particular. The future of the Project looks good, for several reasons: we have a clear idea of where we are going, and the likely pitfalls ahead; concrete work has been done since the Project was instituted, and we can look back and point to our achievements, for instance to obtain additional funds from donors. The prospects for future funding are good, because there is a clearly established need/potential for pigeonpea production in the region; because of the Project's record of past achievements; because of the continuous monitoring that has been built into the Project planning; and because of the clearly demonstrated NARS commitment to the Project.

I am sure you will go back from this Meeting with a renewed sense of purpose that in turn will translate into new technologies for pigeonpea production, and more effective transfer of these technologies to smallholder farmers in eastern and southern Africa.

Good luck, and bon voyage.

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Back row, left to right — S Z Mukuru, J M Gatere, M A Ugen, H Okurut-Akol, K MuiMui, T E E Areke, Umaid Singh, P A Omanga, M Silim-Nahdy, Zodwa Mamba (partly obscured by Kanenga), D J M Marais, H N Soko (behind Moima), J P Esele, A T Daudi, F A Myaka, D K Muthoka.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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