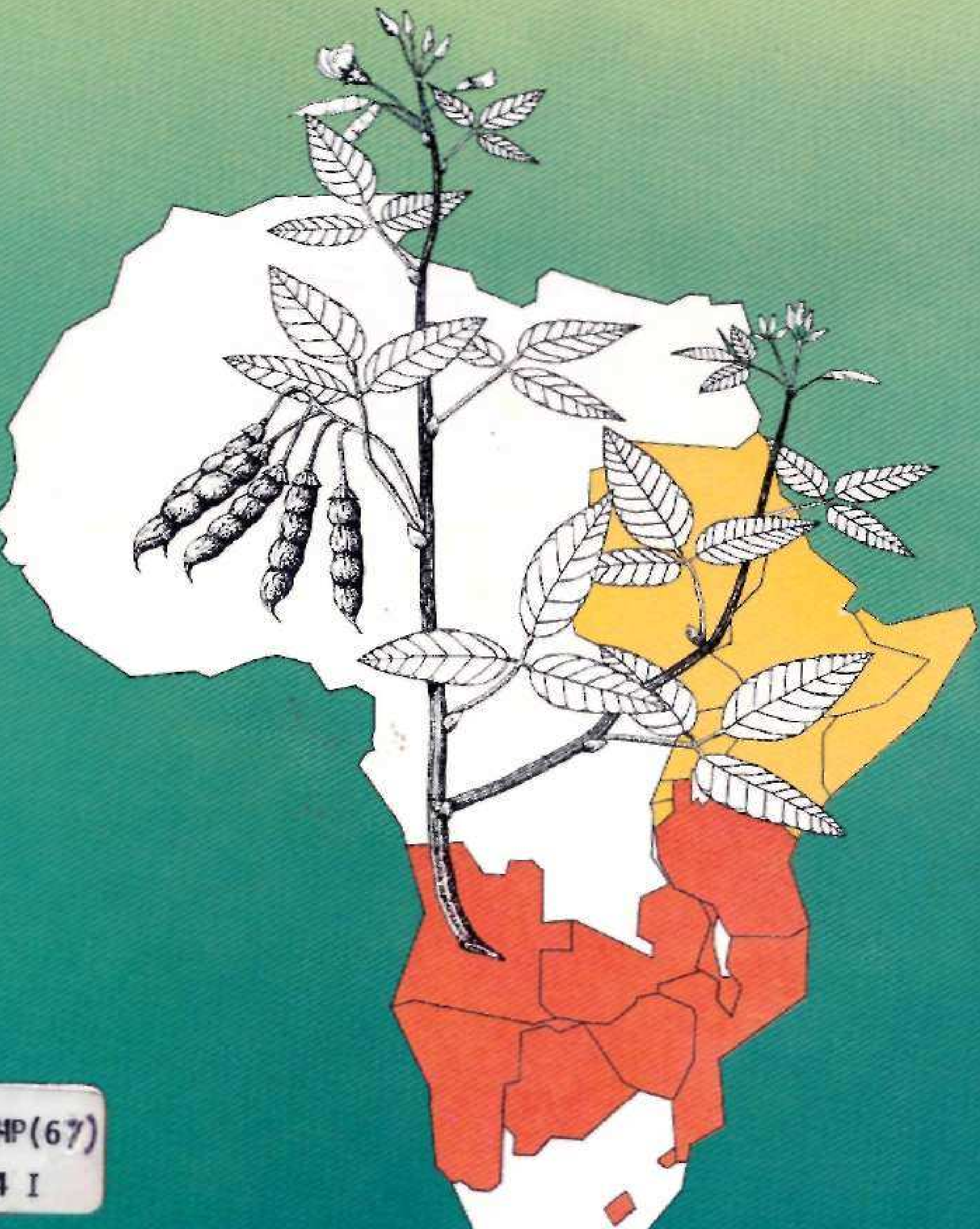
Improvement of Pigeonpea in Eastern and Southern Africa

Annual Research Planning Meeting 1993



International Crops Research Institute for the Semi-Arid Tropics

Abstract

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The ICRISAT/African Development Bank (AfDB) Pigeonpea Improvement Project aims to develop and propagate the use of improved cultivars and management practices among pigeonpea farmers in eastern and southern Africa, and to increase the utilization of this crop in both regions. This publication is a report of the Annual Research Planning Meeting 1993, held at Bulawayo, Zimbabwe, 25-27 Oct 1993 and attended by ICRISAT scientists, AfDB representatives, and NARS scientists from 11 countries. Research progress made since the project was launched is reviewed; the major production/utilization constraints in each country, and ways to alleviate them, are discussed; and workplans (detailing proposed activities, methodologies, budgets, etc.) are presented for collaborative pigeonpea research in eastern and southern Africa.

Résumé

Amélioration du pois d'Angole en Afrique orientale et australe—Réunion annuelle 1993 sur la planification de la recherche, 25–27 octobre 1993, Bulawayo, Zimbabwe. Le but du Projet ICRISAT/Banque africaine de développement (AfDB) d'amélioration du pois d'Angole est de mettre au point des cultivars et des techniques culturales améliorés et de vulgariser leur utilisation en milieu rural de l'Afrique orientale et australe, ainsi que d'accroître l'utilisation de cette culture dans les deux régions. L'ouvrage est le compte rendu de la Réunion annuelle 1993 sur la planification de la recherche, qui s'est tenue à Bulawayo, au Zimbabwe, 25–27 octobre 1993, et a été assistée par des chercheurs de l'ICRISAT, des représentants de l'AfDB et des chercheurs provenant des programmes nationaux des 11 pays. Les progrès faits depuis le lancement du projet sont passés en revue; les principales contraintes à la production et à l'utilisation dans chaque pays et les mesures de les lever sont examinées; et des plans de travail précisant des activités de recherche, des méthodologies et des budgets proposés sont présentés pour des projets collaboratifs sur le pois d'Angole en Afrique orientale et australe.

Resumo

A reunião annual do planejamento das pesquisas para o melhoramento do guando no leste e sul da africa, no ano de 1993, 25–27 de outubro de 1993, Bulawayo, Zimbabwe. O objetivo do projeto para o melhoramento do guando finaniado por ICRISAT e o banco de desenvolvimento africano (AfDB), é para desenvolver e propagar o uso das variedades melhoradas e as tecnicas praticas entre os fazendeiros do guando no leste e sul da africa, e para aumentar a utilização d'esta cultura nas duas regiões. Essa publicação é sobre a reuniõo anual de planejamento das pesquisas em 1993, realizado em Bulawayo, Zimababwe, nos dias 25–27 de outubro de 1993, e participado por cientistas de ICRISAT, representantes do AfDB, e cientistas dos programas nacionais de onze paises. O progresso das pequisas desde o inicio do projeto foi revisado, as maiores limitações da produção e utilização da cultura, as soluções dessas limitações foram debatidas; e os planejamentos do trabalho (detalhando propostas de atividades, metodologia, e os orçamentos etc.) foram apresentadas para pequisas colaborativas sobre guando no leste e sul da africa.

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Bulawayo, Zimbabwe, 25-27 Oct 1993

Edited by

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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
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Introduction

L.K. Mughogho[1]

ICRISAT in Africa

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has a mandate to work on six crops—sorghum, pearl millet, finger millet, pigeonpea, chickpea, and groundnut. These crops are staple diets, key diet supplements, or major sources of income for one-sixth of the world's population, spread over often harsh and rainfall-deficient environments in 48 countries.

ICRISAT is not new to Africa; our partnership with African national programs began 18 years ago. Today we work with NARS in eastern and southern Africa on five major research programs:

- Eastern Africa Regional Cereals and Legumes Program (EARCAL);
- Eastern Africa Regional Sorghum and Millet Network (EARSAM);
- ICRISAT/AfDB Project on Improvement of Pigeonpea in Eastern and Southern Africa;
- SADC/ICRISAT Groundnut Project;
- SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP).

The Goals of Research

The eventual goal of any research program is impact in farmers' fields, the products of research must reach and benefit the farmer. As stated by Merril-Sands and Kaimowitz, therefore, researchers should:

- Focus on real problems and constraints faced by farmers;
- Take into account the agroecological and socioeconomic aspects of farming systems in technology development;
- Ensure that technology transfer groups are aware of technologies available to farmers;
- Obtain feedback from farmers regarding transferred technologies so that the necessary adjustments can be made to future technologies.

Farmer participation in technology development is the key to successful adoption of new technologies by resource-poor smallholder farmers. Only when scientists combine their work with the expertise that farmers have gained over generations, can they put together technologies that are relevant, easily acceptable, and of lasting value.

1. Executive Director, ICRISAT Southern and Eastern Africa Program, P.O. Box 776, Bulawayo, Zimbabwe.

The important role played by women in agriculture has gone unrecognized for many years. Fortunately that is changing; and in the Pigeonpea Project there has been a conscious and deliberate effort to ensure that women farmers are not merely visitors to the station or 'clients' for research products, but full-fledged partners in pigeonpea improvement.

Participatory Research

Farmers can participate in on-farm trials, or can evaluate on-station trials; both forms of participation are central to this project. On-farm trials help to indicate how varieties perform under field conditions; better identify criteria (e.g., plant characteristics) critical to farmers; target varieties more accurately at specific agronomic regions, production systems, or socioeconomic groups; and improve or fine-tune varieties. Farmer evaluation of on-station trials ensures that their perspectives are integrated into the technology development process at an early stage; promotes closer researcher/farmer collaboration; and enhances farmer influence in technology development.

Project Objectives

The ICRISAT/AfDB Pigeonpea Improvement Project for Southern and Eastern Africa was launched in March 1992. Overall, the goal of the project is to strengthen the pigeonpea research capabilities of the national agricultural research systems (NARS) of each of the countries in both eastern and southern Africa, and thus to make the research programs dynamic and sustainable. There are two primary objectives:

- To introduce, test, and select pigeonpea genotypes for adaptation to different agroecological conditions and cropping systems in eastern and southern Africa; and to improve upon local landraces;
- To organize on-farm adaptive testing of selected genotypes, and catalyze commercial production of pigeonpea in appropriate existing and new potential cropping systems.

The specific objectives are as follows:

- To test, select, and develop improved germplasm, and make it available to national programs for adaptive testing and commercial production;
- To develop in cooperation with national programs seed production, storage, and crop protection technologies;
- To strengthen national pigeonpea research and production programs by providing technical advice when requested, and facilitating and undertaking formal and non-formal training of their staff.

Workplans

The African Development Bank requires the project to submit: '.... annual work programme and budget indicating projected activities for that year, in particular those with the national pigeonpea research programmes, together with their cost implications. . . . for its review and approval'.

Why workplans? Workplans are an essential feature of any well-planned research project. They are to the project what a flight plan is to a pilot; a clear route map to your goal or destination, showing the landmarks or milestones en route, and when each milestone should be crossed. They also specify the division of responsibility, and ensure accountability at all levels among scientists and other staff.

This publication is a report of the second Project Review and Planning Meeting. It provides details of annual workplans for each country, including:

- On-farm research;
- Back-up research (e.g., experiments and trials);
- Back-up support activities (e.g., seed multiplication, off-season nurseries);
- Human resource development;
- Meetings, workshops, and conferences;
- Budgets.

ICRISAT-NARS Collaboration

All research under this project is collaborative, as is traditional for projects where ICRISAT is involved. NARS play the leadership role; ICRISAT provides technical support and assistance in human resource development. Equal partnership in all activities-joint planning, joint data analysis, and joint reporting of results—ensures that the work is focused on clearly identified needs, tailored to available budgets, and structured so as to yield results quickly and efficiently.

A Consortium for Pigeonpea Technology Exchange

We believe that one of the eventual aims of this project is to create a consortium for technology exchange in pigeonpea. Such a consortium would:

- Attract, focus, and facilitate inputs from an enlarged range of collaborators;
- Develop linkages between research, extension, seed producers, nongovernmental organizations, farmers, donors, and the private sector;
- Build up a critical mass of diverse institutions and organizations (but with common interests), which can then jointly plan an integrated program for the benefit of pigeonpea farmers.

In conclusion, ICRISAT and the NARS of eastern and southern Africa are grateful to the African Development Bank for financial support of this project. Increased production of pigeonpea will contribute to food security in the two regions, and thereby fulfill the key objective of AfDB support.

Collaborative Pigeonpea Research: A Review of Progress Made Since the Launching Meetings

S.N. Silim[1]

Introduction

In 1991, the African Development Bank (AfDB) approved funding for research geared towards pigeonpea improvement in eastern and southern Africa. Two scientists were recruited; an agronomist for Kenya and a breeder for Malawi. This was in addition to the breeder who had already been posted to Kenya by ICRISAT. The project was formally launched at meetings in Kenya and Malawi in Mar 1992, in which senior administrators and scientists involved in legumes research participated. The most important topics addressed at the meetings were:

- For each country, identification of available resources (ICRISAT support would be limited due to funding constraints), research needs, and constraints to productivity improvement;
- Identification of training needs. The project would make funds available for higher (degree and non-degree) training, but such training should be in line with member countries' research priorities;
- Identification of research priorities, and approaches to tackling the major research problems;
- Drafting a general workplan, the details of which could be finalized later. It was essential that any improved technology developed should reach farmers; a technology transfer component should therefore be included in the workplan;
- Assessing the capability and commitment of each national program to undertake collaborative research.

Recommendations

The discussions leading to the formulation of recommendations dealt with three broad priority areas:

- Technical
- Training
- Other needs

These categories were guidelines rather than rigid demarcations, and it was understood that the priorities were dynamic, and that periodic adjustment may be necessary.

1. Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT, P.O. Box 39063, Nairobi, Kenya

Technical Priorities

Priorities for each country are given in Table 1. Some of these activities could be handled regionally, in either eastern or southern Africa, as described below:

Table 1. Prioritization of technical requirements, by country.

	Priority[1] and requirement[2]					
Country	1	2	3	4	5	6
Angola	RRA	GC	CP	SP	SE	-
Burundi	RRA	V	A	TT	SE	-
Kenya	SP	TT	CP	PH	A	V
Malawi	V	GI	SP	MP	GC	SE
Sudan	A	V	PH	TT	SE	-
Tanzania	V	A	SE	GC	SP	TT
Uganda	RRA	V	PH/A/CP	-	TT	SE
Zambia	SE	A	V	TT	SP	PH

1. 1 = high priority, 6 = low priority.
2. RRA = Rapid rural appraisal, GC = Germplasm collection, CP = Crop protection, SP = Seed production, SE = Socioeconomics, V = Variety development, A = Agronomy, TT = Technology transfer, PH = Postharvest technology, GI = Germplasm introduction, MP = Marketing and processing systems.

Regional Activities for Eastern Africa

Crop protection. Crop protection was felt to be an important aspect, and best treated as a part of variety development, under which it is covered in Table 1. It was agreed that the approach would be through integrated pest/disease management.

An earlier survey had indicated that pests were a major constraint. As a start, a consultant from the region will be recruited to help provide solutions, and will work with national scientists in eastern and southern Africa.

Postharvest technology. Two aspects of postharvest technology were identified: processing and prevention of postharvest losses. It was agreed that responsibility for technology development would be divided, with processing research being undertaken by Kenya and research for the prevention of postharvest losses by Uganda. ICRISAT has not done much work on storage pests; it was felt that greater emphasis should be placed on this aspect in future, since storage pests are a major constraint in the region. Research work on postharvest losses, particularly due to bruchids, is being undertaken in Uganda and we hope the technology developed will benefit the whole region. The research results so far obtained are discussed elsewhere in this publication.

We are expanding the scope of research work on processing. Training courses on processing will be conducted at ICRISAT Asia Center (IAC) in India, and we expect a total of 12 participants from the region for the first course. A resource person (to be identified) will also participate in the training course, and will subsequently initiate the planned research expansion in both eastern and southern Africa.

Socioeconomic studies. Surveys need to be conducted, e.g., on crop marketing, utilization, etc. Part of this work has already started in Kenya and Uganda, where surveys were undertaken on production systems, constraints, and utilization of pigeonpea. The results of the surveys in Uganda are discussed elsewhere in this publication.

Germplasm exchange. It was agreed that countries with strong varietal development programs (e.g., Kenya) should initiate germplasm exchange by sending some of their promising cultivars to cooperating countries for evaluation. Later a regional nursery could be developed, to which cooperating countries could contribute promising lines.

The process has already begun in eastern Africa: a regional nursery of promising short-duration lines is being sent to cooperators. This includes lines from the Kenyan national program. I understand a short-duration line, Kat 60/8 from Kenya, is giving very good yields in Uganda and Tanzania. Kenya is unique in Africa in that it varies in altitude from sea level to over 2000 m. This permits the testing and selection of lines for adaptation to different agroecological zones, particularly those varying in temperature. We believe that promising short-duration lines selected in Kenya and now in the regional nursery could be useful in both eastern and southern Africa. Presently, we have a limited number of nurseries that could be supplied to scientists in the region.

Regional Activities for Southern Africa

Socioeconomic survey. All participants felt that surveys were necessary to collect information on production, constraints, local and export markets, and crop utilization in each country.

Seed production. The availability of seed of improved varieties is a major constraint throughout the region. I hope our deliberations result in the development of an effective approach to overcome this constraint.

Germplasm collection. The opinion was unanimous that germplasm collection in Africa has been inadequate. In most African countries pigeonpea germplasm has not been collected at all. ICRISAT's Genetic Resources Division has greatly intensified its collection activities in the region.

New varieties. All participants expressed a need to acquire new varieties. The development of new varieties through breeding, selection, and introduction of germplasm and/or breeding materials is necessary to improve productivity. ICRISAT scientists in the region have sent a number of nurseries to cooperators, and some lines have been selected for further testing.

Training Needs

The project aims to be sustainable in the long term and not to disintegrate once donor funding ends. To achieve this aim, it is necessary to have a pool of well-trained personnel. It was agreed that training should focus on areas relevant to each country's research priorities. Details are provided in Table 2.

Table 2. Prioritization of training requirements, by country.

		Level of training, number of participants			
Country	Discipline	Technician	BSc	MSc	PhD
Angola	Agronomy	-	-	1	1
	Breeding	-	-	1	1
	Entomology	-	-	1	1
	Pathology	-	-	1	1
Burundi	Agronomy	**3**[1]	1	-	1
	Breeding	-	-	1	1
Kenya	Agronomy	-	-	-	**2**
	Breeding	-	-	-	1
	Entomology	-	-	**2**	-
	Food science	-	-	1	-
Malawi	Agronomy	5	-	1	-
	Breeding	5	-	-	1
	Entomology	-	-	-	1
	Pathology	-	-	-	1
Sudan	Agronomy	**4**	-	-	-
	Breeding	-	-	**1**	-
Tanzania	Agronomy	4	-	1	1
	Breeding	1	-	1	1
	Socioeconomics	1	-	-	-
Uganda	Entomology	-	-	-	**1**
	Breeding	-	-	1	-
	Pathology	-	-	-	1
	Economics	-	-	1	-
	Food science	-	-	**1**	-
Zambia	Agronomy	3	-	1	-
	Breeding	2	-	1	-
	Entomology	-	-	1	-
	Pathology	-	-	1	-
	Food science	-	-	-	1

1. Bold face = high priority.

The project has successfully liaised with mentor and other institutions to place researchers in training or advanced study programs. These researchers are being funded through the project. Four senior national scientists from Kenya, Uganda, Malawi, and Tanzania have been admitted for training courses leading to higher degrees. The eastern African scientists have already started their higher degree studies; scientists from southern Africa will start their studies in Jan 1994. Two technicians, one from Sudan and the other from Kenya, are at IAC for 6-month in-service training. Burundi's request that a technician be trained to degree level was approved, but we await placement in a university.

Other Needs

Several other needs (operational funds, equipment, etc., Table 3) had to be met for successful implementation of the project. Lack of operational funds was felt to be a particularly serious problem. Pigeonpea is an important crop and has potential for the future, but is still neglected. With initial supplemental funding from ICRISAT, and particularly once research impact can be demonstrated, governments throughout the region would give pigeonpea research more priority.

Table 3. Prioritization of funding/equipment needs, by country.

	Priority[1] and requirement[2]		
Country	1	2	3
Angola	-	-	-
Burundi	OF	V	E
Kenya	*OF*	V	E
Malawi	OF	V	E
Sudan	OF	E	-
Tanzania	OF	V	E
Uganda	OF	V	E
Zambia	OF	V	E

1.1 = highest, 3 = lowest.
2. OF = Operational funds (labor, fuel, supplies, allowances, incentives, etc.), V = Vehicles, E = Equipment.

ICRISAT has responded to these needs by cutting back funding on some of its activities at Lilongwe and Nairobi, and increasing operational funding for collaborative research with the national programs.

Plan of Action

Nomination of National Coordinators

National coordinators for Burundi, Kenya, Sudan, Uganda, Malawi, Tanzania, and Zambia have been nominated.

Development of Workplans

During the last 1 year ICRISAT scientists have travelled to most of the participating countries to draw up detailed workplans. However, we have not received detailed reports of the research work undertaken, except from Sudan. Once the reports are compiled, annual/progress reports for the region will be prepared and circulated to member countries.

Release of Funds

ICRISAT has released partial funding for collaborative research on pigeonpea, to supplement NARS resources. We have had problems in receiving certified reports on the usage of funds. Our policy is not to disburse funds until we receive the previous season's report.

ICRISAT/AfDB Pigeonpea Improvement Project in Eastern and Southern Africa

S. Tuwafe[1], S.N. Silim[2], and Laxman Singh[2]

Introduction

In eastern and southern Africa, pigeonpea is grown as an intercrop, or mix-cropped with cereals, short-duration legumes, or other long-duration annuals (Laxman Singh 1991, Silim et al. 1991). The varieties used in eastern and southern Africa are mainly medium- and long-duration landraces with large seeds and slow initial growth rates (Silim et al. 1991). Most long-duration pigeonpea is grown in drought-prone areas, and may fail to produce grain in years of severe drought. The landraces are very sensitive to temperature and photoperiod. Concerted research efforts have resulted in the development of short-duration varieties that can escape drought and provide higher yields. This allows farmers more flexibility, and has facilitated the use of pigeonpea in different cropping systems.

The crop is grown in several countries in Africa; the major producers are Kenya, Malawi, Mozambique, Tanzania, and Uganda. Estimates for the area under pigeonpea in these countries range from 300 000 to over 500 000 ha (Heemskerk 1986), which we believe is an underestimate. For example, a large proportion of pigeonpea grown (mainly for consumption as green pods) in small gardens, hedgerows, and border rows is not included in these estimates. Sudan has over 15 000 ha grown as irrigated border rows in the Gezira scheme, but this is not included in production statistics. The area reported for Uganda (50 000-90 000 ha) is clearly an underestimate. Surveys conducted between 1990 and 1993 in Kenya, Tanzania, and Uganda suggest that the total pigeonpea area in these countries is well over 800 000 ha. Similarly, the reported productivity of 300-500 kg ha^{-1} (Omanga et al. 1991) is an underestimate because it does not include a large proportion consumed as green peas (Silim and Omanga 1992).

Productivity Constraints

The productivity of pigeonpea is low, often due to inadequate and variable plant density, drought stress, and losses due to diseases and insect pests. The pod borer (*Helicoverpa armigera*), pod-sucking bugs (*Clavigralla* spp), and the pod fly (*Melanagromyza obtusa*) are the major pests (Reed and Lateef 1990). Diseases that cause major losses are fusarium wilt (*Fusarium udum*) and leaf spot (*Cercospora cajani*) (Reddy et al. 1990). Wilt-related losses as high as 50%, and sometimes 100%, have been reported in Malawi (Soko 1992).

1. ICRISAT Pigeonpea Project, P.O. Box 1096, Lilongwe, Malawi.

2. Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT, P.O. Box 39063, Nairobi, Kenya.

With the introduction of new cultivars that mature in 90-130 days, it is now possible to grow short-duration pigeonpeas in areas prone to drought and to obtain two crops per year in areas with bimodal rainfall. In addition, short-duration pigeonpea can be introduced in areas where intensive management is a feasible option to maximize production. Scientists from the Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT, and NARS in the region, working in close collaboration, have identified areas suitable for short-duration pigeonpea. Before commercial cultivation can be initiated, more research is required on the agronomy of this new crop and on insect pest and disease management, both in the field and in storage.

Utilization

In southern and eastern Africa pigeonpea is consumed mainly as cooked whole dry seed or as green peas; split pigeonpea is used by farmers in southern Tanzania and Uganda, There is considerable scope to increase utilization (both domestically and for export), and thus increase production and farmers' incomes.

The export potential of split pigeonpea (*dhal*) is high. There are large agro-processing plants in Kenya, Malawi, and Tanzania which dehull pigeonpea seed for local consumption (mainly by people of Asian origin) and for export to India, the Middle East, Europe, and North America. At present, both processing capacity and export demand far exceed production levels. Similarly, demand for export of whole grain is greater than supply (Shah 1992).

A recent survey conducted in the major production areas in Kenya indicated that a large proportion of pigeonpea is eaten as green peas (Silim and Omanga 1992). The development of genotypes with characteristics preferred by green pea consumers will stimulate production. These are also indications that a substantial potential export market exists for green peas. Already, a few commercial farms in Kenya have started growing pigeonpea for export as green peas to the UK. By promoting processing and widening the scope of utilization of pigeonpea for local consumption and export, both production and productivity can be substantially increased.

The Pigeonpea Project

Despite the importance of pigeonpea in Africa, research efforts in the region have been limited. At a meeting in 1986, African scientists involved in grain legume improvement research in eastern and southern Africa recommended that ICRISAT should become actively involved in pigeonpea improvement in the region. As a result, ICRISAT's pigeonpea improvement project in eastern and southern Africa was started in late 1989 with the appointment of a scientist in Nairobi, Kenya. In 1991, with funds from the African Development Bank (AfDB), two additional scientists were appointed, one each in Kenya and Malawi.

Objectives

Information is lacking on pigeonpea cultivars suitable for intercropping in drought-prone areas, and on the role of pigeonpea and other short-duration legumes in maintaining sustainability. This project aims at collecting information on production systems and constraints. The major objectives of the project are to:

- Develop improved cultivars;
- Identify potential niches for pigeonpea introduction;
- Develop improved production packages.
- Promote increased production;
- Strengthen NARS research capabilities;
- Assist NARS in human resource development.

Cultivar Development

A major objective is to develop improved, high-yielding long- and medium-duration pigeonpea cultivars with acceptable grain quality. The emphasis will be on selecting genotypes that are tolerant to major biotic (pests and diseases) and abiotic (drought) stresses, and understanding the adaptation of the crop to local photoperiod and temperature conditions. Germplasm evaluation will permit us to focus our crop improvement strategy and to provide NARS in the region with cultivars better adapted to local/specific agroecological conditions.

Research on short-duration cultivars will aim to improve grain size and color (most of the lines developed earlier at the ICRISAT Asia Center (IAC) in India have small brown seeds), and tolerance to pests, diseases, and drought. We are also screening and selecting genotypes for adaptation to varying temperatures, which will permit us to grow pigeonpea in areas from near sea level up to about 2000 m altitude.

Potential Niches for Pigeonpea

It is important to identify potential niches into which new cropping systems with short-duration pigeonpea will fit. Geographical Information Systems (GIS) will be used to characterize agroecological zones to determine suitable environments for pigeonpea cultivation, and identify potential constraints. Subsequently, advanced material will be evaluated in cooperative regional trials at appropriate locations.

Production Packages

The project will aim to develop improved production packages for traditional cropping systems based on long- and medium-duration pigeonpea. Production packages including pest management strategies will also be developed for short-duration pigeonpea.

Pigeonpea provides long-term benefits in terms of nitrogen fixation, increased phosphorus availability, and improved soil structure. Studies will be undertaken to quantify the role of pigeonpea in the sustainability of pigeonpea-based cropping systems.

Increasing Production

The overall objective of the project is to promote increased pigeonpea production by:

- Increasing utilization options by selecting vegetable types for local consumption and export, and developing cheaper dehulling methods;
- Catalyzing the development/improvement of processing methods, particularly for export;
- Developing new recipes for pigeonpea dishes;
- Developing improved storage practices.

Training

We believe that the collaborative research under this project will help strengthen the research capabilities of our partners in the NARS. This objective will also be specifically addressed by training programs, both short-term and those leading to M Sc and Ph D degrees.

Organization and Research Strategy

Research efforts are collaborative, involving scientists at IAC, NARS in the region, and the ICRISAT regional program in eastern and southern Africa. The various project activities, which together form a comprehensive research agenda, are briefly described below.

Research in Malawi and Kenya

The research programs in the host countries, Malawi and Kenya, involve:

- Extensive screening of germplasm and breeding lines;
- Hybridization of introduced genotypes with local varieties and landraces;
- Development of early segregating populations;
- Collaborative on-farm trials, etc.

Materials are first tested in Malawi and Kenya, and then sent to collaborators in the region for further evaluation. In the 1992/93 crop season, 31 pigeonpea lines (Tables 1, 2) of varying maturity durations were included in a preliminary yield trial and observation nursery, and later sent to collaborators in the region for agronomic evaluation (Table 3). For the past few years, scientists at IAC have been sending large numbers of germplasm and breeding materials to collaborators in the region for evaluation and selection. ICP 9145, a germplasm accession originating from Kenya, was identified at IAC as resistant to fusarium wilt. After extensive testing, it was released in Malawi during the 1986/87 crop season, and now accounts for about 20% of the total pigeonpea area in Malawi.

In eastern and southern Africa, pigeonpea is grown from sea level to about 1800 m altitude. Understanding the effect of temperature and photoperiod on phenology, plant height, and yield will permit us to characterize our germplasm resources and develop breeding lines adapted to specific environments. Reports indicate that pigeonpea is extremely sensitive to photoperiod and temperature, with regard to phenology, plant height, biomass, and grain yield. This sensitivity is a major constraint to the development of production systems, management practices, and improved cultivars. For example, instability in plant height makes spraying and harvesting difficult. Similarly, sensitivity in phenology, which results in delayed maturity, may intefere with traditional cropping sequences, where there is little time between the pigeonpea harvest and the sowing of the succeeding crop.

Table 1. Yield and yield components of entries in the short-duration pigeonpea trial, Kiboko, Kenya, 1992/93.

Line	Seed color	Days to Flowering	Days to Maturity	Plant height (cm)	100-seed mass (g)	Harvest index	Grain yield (t ha^{-1})
ICPL 87091	C	64	113	72	11.6	0.50	2.71
ICPL 86005	DB	62	108	65	12.5	0.43	2.60
ICPL 83016	CS	67	117	83	12.4	0.50	2.16
ICPL 87102	LC	62	108	64	11.7	0.47	2.02
ICPL 87101	B	60	98	56	12.5	0.35	2.00
Kat 60/8	CS	84	147	216	11.6	0.22	1.88
ICPL 87 W	C	62	100	54	10.6	0.42	1.88
ICPL 151	LB	61	99	51	10.2	0.44	1.83
ICPL 87104	CS	59	101	52	11.1	0.40	1.73
ICPL 87 B	B	60	103	54	10.3	0.33	1.70
ICPL 89026	CS + B	59	99	45	10.0	0.42	1.34
K0-36/10	CS	122	151	237	11.4	0.21	0.95
Mean		69	112	87	11.3	0.39	1.90
SE		0.8	1.5	6.9	0.25	0.051	0.253
CV (%)		2.1	2.4	13.7	3.9	22.5	23.1

1. B = brown, C = cream, LC = light cream, DB = dark brown, LB = light brown, CS = cream speckled.

Table 2. Yield and yield components of entries in the determinate short-duration pigeonpea trial, Chitedze, Malawi, 1992/93.

Line	Days to 50% flowering	Days to Maturity	Plant height (cm)	Dry matter (t ha^{-1})	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 88023	68	117	79	5.91	14.0	2.88
ICPL 86005	68	116	96	7.03	13.0	2.87
ICPL 90028	69	117	78	5.80	15.0	2.87
ICPL 87101	68	116	88	6.96	13.0	2.70
ICPL 88027	68	120	81	6.61	13.0	2.66
ICPL 87105	70	120	82	5.49	12.0	2.14
ICPL 90029	68	116	90	4.58	14.0	2.14
ICPL 83024	67	116	78	5.44	15.0	2.00
ICPL 90024	66	108	72	2.83	11.0	1.71
ICPL 87104	64	108	77	2.36	11.0	1.71
ICPL 87	67	116	66	3.97	11.0	1.69
ICPL 84031	66	116	61	3.02	10.0	1.62
ICPL 88025	63	108	67	3.06	13.0	1.53
ICPL 86012	65	108	77	3.69	10.0	1.50
ICPL 89031	63	116	64	3.56	15.0	1.39
ICPL 85012	63	108	60	2.42	11.0	1.25
ICPL 90013	73	117	83	2.16	11.0	0.29
ICPL 87109	73	117	91	1.67	14.0	0.10
ICPL 89030	67	113	84	1.94	11.0	0.04
Mean	66	114	77.6	4.13	12.4	1.74
CV(%)	2.2	2.4	8.5	22.6	6.6	13.4

Table 3. Nurseries distributed in eastern and southern Africa, 1992/93.

Country	Number of locations	Number of nurseries	Number of entries
Sudan	4	4	12
Uganda	4	5	12
Kenya	4	>30	>600
Malawi	8	19	>400
Mozambique	1	1	130
Namibia	1	3	56
Tanzania	3	5	92
Zambia	1	5	92

The Kenya transect, where daylength varies by less than 30 min over an altitude variation from 50 m to 2000 m above sea level, was used to evaluate pigeonpeas varying in maturity period. Preliminary results indicated that in short- and extra-short-duration pigeonpea, reduction in temperature (increase in altitude) causes delayed flowering and reduced height (Table 4). With long-duration landraces, however, reduction in temperature *hastened* flowering (Table 5), reduced height and biomass, and *increased* pod set. This differential response was particularly pronounced in lines obtained from low altitude (near the coast), which behaved like long-duration types at low altitude, but like medium-duration types (but with heavy pod set) at high altitude (2000 m).

Table 4. Effect of temperature on phenology, height, grain yield, and 100-seed mass of 121 short-duration pigeonpea lines, Kenya, 1992/93.

	Kiboko[1]		Katumani		Kabete	
Trait	Range	Mean	Range	Mean	Range	Mean
Days to flowering	52-100	60	63-137	76	83-116	90
Days to maturity	95-158	106	119-179	128	136-178	109
Plant height (cm)	36-249	77	34-153	58	30-124	57
100-seed mass (g)	6.9-13.3	10	8.8-15.9	11.2	9.1-15.1	11.1
Grain yield (t ha^{-1})	0.73-7.07	2.2	-	-	0.91-4.93	2.14

1. Approximate mean temperatures: Kiboko 23, Katumani 19.2, and Kabete 17.8°C.

Table 5. Effect of temperature on phenology of long-duration pigeonpea, Kenya, 1991/92.

		Days to flowering	
Origin of material	Number of entries	Kibwezi[1]	Katumani[2]
Long-duration cultivars from India	8	145	135
Landraces from Tanzania (altitude 20-590 m asl)	16	123	117
Landraces from Kenya and Tanzania (900-1500 m asl)	19	255	197
Mixed populations and market samples from Kenya (680-1530 m asl)	9	243	131

1. Low altitude with high mean temperature (approx 25*C).
2. High altitude with low mean temperature (approx 19.2*C).

ICRISAT-NARS Collaboration

Research collaboration between ICRISAT and the NARS in the region dates back to 1986, before the project was established. This project is in that sense an extension of earlier work, utilizing the skills and comparative advantages of each partner as best possible. IAC will be the primary source for material showing genetic variability; its facilities and skills will be used for making crosses, for training, and for GIS applications. ICRISAT scientists in the region will evaluate promising materials and identify superior lines. These would be sent to NARS for further work. In Kenya, for example, the altitudinal variation can be used to screen germplasm for adaptation to temperature at constant photoperiod.

Collaboration with NARS in the region will help to solve problems of national or regional importance. The network brings together different countries to determine research priorities, identify problems of common concern—which need to be solved collectively—and decide which country(ies) within the network will take primary responsibility for research on each problem. At the Project Launching Meetings in Mar 1992 in Nairobi and Lilongwe (Silim et al. 1992), postharvest technology, germplasm exchange, and crop protection were considered to be regional research priorities. Work plans based on each country's research priorities were developed jointly by ICRISAT and NARS scientists. The project will supply nurseries and trials to collaborators in the region on the basis of these workplans.

ICRISAT and NARS scientists jointly visit on-going trials in the region during the growing season. Workshops and seminars are conducted by the project so that collaborators in the region can meet and exchange ideas, discuss results, and formulate future workplans. Furthermore, the project aims at improving human resources in each collaborating country based on the needs identified at the Launching Meetings (Silim et al. 1992).

In order to assess the impact of technologies developed through the project, surveys will be conducted every 2 years in areas where the improved varieties are being grown, marketed, and/or consumed. This will also help to identify the constraints limiting technology adoption.

Two areas have been identified where expertise is lacking: processing and utilization, and pest management. A consultant will be hired for each of these areas who, after the necessary surveys, will initiate appropriate research plans to strengthen the project. He/she will also conduct training courses for NARS and project scientists in the region.

References

Heemskerk, W. 1986. Pigeonpea in Mozambique. International Pigeonpea Newsletter 5:14-16.

Laxman Singh. 1991. Overview of pigeonpea improvement research: Objectives, achievements, and looking ahead in the African context. Pages 5-16 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-

27 Jun 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Omanga, P.A., Shakoor, A., and Siambi, M. 1991. Pigeonpea production and research in Kenya. Pages 101-107 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop 25-27 Jun 1990, Nairobi, Kenya (Laxman Singh, Ariyanayagam, R.P., Silim, S.N., and Reddy M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Reddy M.V., Sharma, S.B., and Nene, Y.L. 1990. Pigeonpea disease management. Pages 303-348 *in* The Pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds.). Wallingford, Oxon, UK: CAB International.

Reed, W. and Lateef, S.S. 1990. Pigeonpea: pest management. Pages 349-374 *in* The Pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds.). Wallingford, Oxon, UK: CAB International.

Shah, R. 1992. Agroprocessing industry for dehulling grain legumes in Kenya—status and potential growth. Pages 53-56 *in* Consultative Group Meeting on Production and Agroprocessing of sorghum and pigeonpea in Kenya (Laxman Singh, Mukuru, S.Z., Silim, S.N., and King, S.B., eds.). Nairobi, Kenya: Ronkai General Supply.

Silim, S.N. and Omanga, P.A. 1992. Survey of pigeonpea based production systems, usage and constraints in the major pigeonpea production areas of Kenya. Nairobi, Kenya: Eastern Africa Cereals and Legumes (EARCAL) Program, ICRISAT and Machakos, Kenya: National Dryland Farming Research Centre, KARL 16 pp.

Silim, S. N., Johansen, C., and Chauhan, Y.S. 1991. Agronomy of traditional and new cropping systems of pigeonpea and potential for eastern Africa. Pages 17-30 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop 25-27 Jun 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V. eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Silim, S.N., Tuwafe, S., and McGaw, E.M. (eds.) 1992. Pigeonpea in eastern and southern Africa: summary proceedings of the Launching Meetings of the African Development Bank/ICRISAT Collaborative Pigeonpea Project for eastern and southern Africa, 12-18 Mar 1992, Nairobi, Kenya; and 30-31 Mar 1992, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 72 pp.

Soko, H.N. 1992. Pigeonpea research and development in Malawi. International Pigeonpea Newsletter 16:59-63.

Assessing the Impact of Research

David D. Rohrbach[1]

Introduction

First let me acknowledge that I know relatively little about pigeonpea production and consumption. The following discussion, correspondingly, summarizes some generic principles under which assessments of the impact of research can be used to guide and monitor research output and to allocate research resources. These principles apply across crops and cropping systems, and can be used by both economists and biological scientists.

Impact assessment has become an increasingly prominent issue for research programs as resources, both funding and manpower, become more constraining. International donors, in particular, now demand greater accountability over their investments in international and national research programs; more rapid payoffs; and clearer evidence of the levels and probabilities of proposed results. National governments are also beginning to demand better evidence of investment returns. Funding constraints are forcing national research programs themselves to more carefully allocate limited resources to specific projects offering the highest payoffs.

In effect, the funding institutions have questioned the proclivity of scientists to suggest their research is likely to yield high impact: 'tomorrow'... or 'with another season of data'... or 'with another commitment of funding'... or 'if extension does its job'... or 'if the seed gets multiplied'.

In many cases, such questions are appropriate. Many scientists need to be challenged to prove the value of their efforts in the fields of small-scale farmers. All scientists need to incorporate a component of impact assessment into their planning, monitoring, and self-evaluation.

Impact assessments are most commonly used for three purposes:

- To assess the products of past investments in research and justify ongoing investment;
- To identify constraints to the adoption of technologies and thereby improve the returns on research;
- To prioritize the allocation of future research investments.

Each of these objectives is briefly discussed below.

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Impact and Investment Decisions

The most common form of impact assessment is an *ex post* evaluation of research results. Often, successful cases are targeted, and evidence gathered to justifying further investment funding. The success of a given investment is judged on the basis of the value of the return to the ultimate clientele.

Agricultural economists commonly calculate rates of economic return on investments of funding and manpower allocated to both technology generation and dissemination. The full set of research and extension costs are compared with the additional value of production achieved as a result of the adoption of improved technologies. In more complicated models, the distribution of benefits to producers and consumers are distinguished.

These rates of return are usually well above the average rates of return on investments in other parts of the economy, and economists therefore argue for continuing agricultural research funding.

These evaluation measures can be extended with assessments of the contributions of agricultural research to the achievement of national goals. We can measure the impact of technological change on household and national food security, on household incomes or the growth of overall national income, or on environmental sustainability. In each case the principles are the same. The full costs of developing a technology are compared with the broad benefits derived from using this technology.

Care must be taken to avoid inferring systemic returns from the results of specialized cases. Investments yielding no new technologies must still be considered as costs. Further, if technology is developed but remains unapplied, the impact is zero. The return on investment in research is negative, even if technologies have been successfully developed. But the use of impact assessments to expose such circumstances can encourage scientists to accept at least partial responsibility for facilitating the adoption of their technologies by farmers.

Assessment of Constraints to Adoption

Given the dependence of research returns on technology adoption, scientists of all disciplines must be concerned with identifying constraints to adoption. In the past, agricultural research scientists have too often simply blamed extension workers for not delivering the message about improved technology. Input suppliers have been blamed for not making improved inputs available. Policy makers have been blamed for marketing constraints and non-remunerative prices. But farming systems research efforts have shown that often it is the technology itself that is to blame. Many technologies offering high yields do not offer high profits. Some technologies that perform well on the research station do poorly under the agroeconomic conditions commonly prevailing among small farmers. Frequently, technologies developed for sole-cropped systems do not fit the more complex crop-livestock systems that characterize the small-scale farm.

Impact assessments can provide guidance for resolving constraints on technology adoption. This includes an assessment of whether the technology is appropriate for the farming system, and a review of institutional and policy constraints to adoption. It requires careful judgement about whether biological, socioeconomic, institutional, or policy constraints are binding.

As noted earlier, impact does not occur when a variety is released. How should research scientists, particularly crop breeders, treat seed multiplication and distribution constraints? In some cases seed companies are simply reluctant to produce the improved cultivar. In others, multiplication may take place, but dissemination is slow. One must then judge whether adoption will take place if seed is available. Even if seed multiplication and distribution constraints are resolved, the improved variety may ultimately prove unacceptable to the farmer. This implies that impact assessments of the adoption of improved varieties should start by verifying the performance of the cultivar in the most likely growing conditions, evaluate the acceptability of the cultivar to farmers, and then work back through an assessment of constraints to seed multiplication and distribution.

Broadly focussed impact assessments can also highlight second generation research problems or potential spillover effects. An improved pigeonpea variety may offer higher yields when rains are favorable but higher risks of crop failure, compared to local landrace varieties, when the rains fail. Farmers may accept a short-duration cultivar, but cite concerns about insect damage and the high costs of insecticide. Some farmers may be primarily concerned about grain yield. However, as population densities rise and land pressures become more severe, increasing importance may be attached to stover yield and value. Tall varieties may offer more stover while short varieties ease the labor requirements of grain harvest. We need to be concerned, not simply with whether farmers are willing to accept a particular released cultivar, but also with the characterization of the evolving demand for alternative grain and plant traits. A more widely focused survey with a larger number of hypotheses can help improve payoffs to research both in the short and longer terms.

Low rates of technology adoption are, perhaps, most commonly blamed on inadequate production incentives. Frequently, we hear demands for higher prices and protected markets. Yet these solutions are not always in the best interests of small-scale farmers. Many pigeonpea producers in drought-prone regions may more commonly buy grain than sell it. High producer prices favor the few better endowed farmers able to sell grain, but not the larger number of more poorly endowed farmers who purchase a part of their food supply. Efforts to extract grain for use by urban consumers and urban industry can translate into food shortages in the rural market.

Assessment of Research Priorities

Impact assessments can also be used to evaluate the probable returns to future research endeavors and correspondingly to determine the priorities for future research. When agricultural research is planned, the products of this research must be defined in sufficiently exact terms to identify where the results will be applied, who will be affected, and the level of potential impact. Rather than resorting to the nebulous goals of improving pigeonpea production or reducing insect damage, research scientists need to be challenged to identify the numbers of farmers or hectares affected and quantify the expected yield gained or loss prevented. This implies a judgement about the probability of research success, an evaluation of the probable extent of technology adoption, and perhaps most importantly, the timing of technology adoption.

For such *ex ante* assessments of research impact to provide a consistent measure for setting funding priorities, the underlying units of measure must be consistently defined. Scientists and research managers must work together in an iterative manner to assure a degree of commonality in predictions of research results. Thereafter, projects can simply be rated for funding priority. Those projects affecting the largest numbers of people or offering the largest and most immediate yield, income, or welfare gains will be funded first. Projects offering less probable or smaller returns for more limited numbers of farmers may only receive funding if resources permit.

Such *ex ante* impact assessment provides a set of milestones for research accomplishment, particularly if the timing of research results and expected impact are well defined. These milestones can be used to monitor research output and ultimately evaluate research success. Further, the delineation of expected impact forces scientists to consider the possible constraints to technology adoption at an early date. Researchers have less incentive to simply develop a technology for transferral to extension agents and the market. Instead, they are held partly responsible for ensuring that constraints to adoption are resolved and the technology is ultimately adopted. This encourages stronger and earlier links with individuals and institutions involved with technology dissemination and with farmers. The process itself improves the probability of research success.

Who is Responsible for Impact Assessment?

Assessments of research impact are commonly viewed as the responsibility of economists. Yet the accuracy of these assessments, and their use in improving the level and probability of future impact depends on the participation of scientists from different disciplines. Crucial data are often available only from biological scientists. Similarly, it is often difficult for economists alone to evaluate biological constraints to adoption.

More importantly, if impact assessments are to be used to prioritize research and increase future impact, they must be incorporated into every research plan. Annual project workplans can readily incorporate descriptions of the type, timing, and regional targets of expected outputs. Annual reviews of research results can readily incorporate a reconsideration of expectations and progress. The transparency of objectives facilitates reallocation of resources as necessary, to maximize the probability of impact and the likelihood that future levels of research funding will rise, rather than fall.

Research Reports

ICRISAT'S Research on Pigeonpea in a Global Context

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Introduction

This paper gives a brief overview of ICRISAT's current research agenda for pigeonpea, with particular emphasis on aspects relevant to eastern and southern Africa. From Jan 1994, ICRISAT will enter a new 5-year Medium Term Plan (MTP) period. As part of the MTP planning process, which began over 2 years ago, we have prioritized pigeonpea research on a global basis in areas where ICRISAT has a comparative advantage. This paper concentrates on studies in progress and those projected for the MTP period. Although presented here under disciplinary headings, most research work referred to is of a collaborative nature, involving ICRISAT and NARS scientists from different disciplines, and advanced laboratories in various countries.

Genetic Resources

A prerequisite to any genetic improvement effort is the availability of a germplasm base containing a wide variability of traits of possible importance to crop improvement. ICRISAT houses the world germplasm collection of pigeonpea, currently over 12 000 accessions. This includes 325 accessions of related wild species containing traits of known and potential value for improving cultivated pigeonpea. ICRISAT's Genetic Resources Division (GRD) collects, evaluates, maintains, and disseminates upon request these germplasm accessions. These accessions represent a vast range of genetic variation; additional variation is generated by ICRISAT's plant breeders and cell biologists. The main challenge is to define what traits are needed for pigeonpea improvement: having done so, there is a good chance of finding them within the germplasm available. Detailed information can be obtained from the Pigeonpea Germplasm Catalog or the computerized germplasm database produced by GRD.

Genetic Enhancement

Over the previous decade at least, ICRISAT has emphasized shortening the duration of pigeonpea while maintaining yield potential. This has resulted in the development of a diverse range of short-duration (SD, 110-140 days from sowing to maturity in the

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environment of Hyderabad, India) and extra short duration (ESD, 90-110 days) genotypes. Diversity is mainly with respect to growth habit (e.g., from determinate to indeterminate types), seed characteristics, and yield potential in different environments. These SD and ESD genotypes are targeted at:

- Fitting into crop rotations, usually of recent origin (e.g., the pigeonpea/wheat rotation now common in subtropical northern India);
- Exploiting the shorter duration to escape terminal drought stress in growing periods delimited by soil moisture availability;
- Higher latitudes—flowering in SD and ESD genotypes is less sensitive to photoperiod (pigeonpea has a short-day photoperiod response) and they can thus flower and reach maturity in the short summer (but with long photoperiods) characteristic of high latitudes;
- Multiple harvest systems—SD and ESD genotypes remain perennial even with shortened duration and determinant growth habit.

Research has also continued on medium-duration (MD, 140-200 days to maturity) and long-duration (LD, 200 days) pigeonpea, but to a decreasing extent over recent years. These genotypes are targeted at traditional intercropping and mixed cropping systems, and evolving agroforestry systems (as a perennial component). The emphasis has been on increasing yield stability by incorporating:

- Resistance to fusarium wilt and sterility mosaic disease (which is severe in South Asia); e.g., ICPL 87119, recently released in India, combines both these resistances;
- Tolerance to *Helicoverpa* pod borer and pod fly; e.g., ICPL 332 with tolerance to pod borer;
- Reduced maturity duration to minimize the risk of terminal drought stress; e.g., ICP 9145 in Malawi (which is also wilt-resistant).

Another unique contribution of ICRISAT's plant breeding efforts has been the development of pigeonpea hybrids—ICPH 8 was the world's first hybrid pigeonpea to be released (in India in 1991). Although increased yield with hybrid vigor has been adequately demonstrated in ICPH 8 (30-40% yield increase over parents or comparable controls) and other more recent pigeonpea hybrids, there are problems in hybrid seed production because male steriles based on genetic male-sterility are hard to identify. Research is now in progress to identify and eventually utilize cytoplasmic male-sterility in hybrid seed production. Although the hybrids produced have high yield potentials, they are susceptible to the major pests and diseases in India. There is thus a need to incorporate pest and disease resistance into the male-sterile base; this is under way.

The partial outcrossing behavior of pigeonpea allows the hybrid option, but makes it difficult to maintain varietal purity. Cleistogamous floral characteristics have been identified which virtually ensure self-pollination. This characteristic is controlled by a single recessive gene and is thus being backcrossed into successful varieties and advanced lines.

Pigeonpea breeding efforts, including crosses with compatible related wild species, have resulted in a diverse range of plant types and characters, each of which shows promise in particular situations. These include:

- Dwarf characteristics that permit easier management (e.g., spraying of insecticide);
- Branching patterns ranging from uniculm to profuse;
- Variations in leaf size and number;
- Inflorescence types from dense cluster to well separated pods (which may minimize damage by certain insect pests);
- Different pod and grain quality parameters;
- Vegetable types in various backgrounds (e.g., SD, with 7-8 seeds pod^{-1} and 100-seed mass >12 g).

Cell Biology

Previously incompatible related wild species have recently been successfully crossed with cultivated pigeonpea, using embryo rescue techniques. For example, crosses have been made with the wild species *Cajanus platycarpus,* which has useful traits such as earliness, growth vigor, salinity tolerance, and phytophthora blight resistance. Recent research has also developed protocols for regeneration of pigeonpea from tissue culture, and demonstrated that genetic transfer of genes via *Agrobacterium tumefaciens* is feasible. This has opened the way for genetic transformation of pigeonpea using the latest techniques available.

Crop Quality

Vegetable, grain, and other uses of pigeonpea have been cataloged. Physical (e.g., grain size and color) and chemical (e.g., protein and mineral content) parameters have been quantified for various genotypes. Genotypic differences in consumer preferences for the established pigeonpea food products have been evaluated through taste panels. Further, alternative and novel uses for pigeonpea products have been identified (e.g., for making noodles and *tempeh* in Southeast Asia).

To enhance utilization and nutritive value of pigeonpea for food uses in African countries, dehulling methods should receive more attention. Laboratory methods to study the dehulling characteristics of different genotypes have been standardized at ICRISAT Asia Center (IAC), but these need to be adapted to African conditions.

Physiology/Agronomy

Substantial genotypic differences in response to drought stress have been found within the ESD, SD, MD, and LD maturity groups. Plant traits conferring drought resistance have been identified and are awaiting exploitation in breeding programs. Drought stress can thus be alleviated by exploiting these traits and drought escape mechanisms, and by better fitting crop duration to periods of probable soil moisture availability.

Short-duration pigeonpea is particularly sensitive to excessive soil moisture. A pot screening technique to quantify genotypic response to waterlogging has been developed and sources of tolerance identified. Their incorporation should improve yield stability in pigeonpea (particularly ESD and SD types) grown in regions prone to intense rainfall events and having soils of high clay content.

Various studies are in progress aimed at understanding nitrogen (N) cycling and enhancing N inputs in pigeonpea-based cropping systems. High-nodulating genotypes better able to fix N are being identified by using ^{15}N natural abundance techniques. Non-nodulating types, which are useful as non-fixing controls in studies to quantify N-fixation, have also been identified. The residual effects of pigeonpea in cropping systems, primarily in terms of fixed N, are also being quantified. Detailed root quantification studies are permitting the development of models to describe root processes.

Earlier studies showed that pigeonpea has a unique ability to access iron-bound phosphate, through excretion of piscidic acid from its roots. Follow-up studies are planned to more clearly understand phosphorus requirements and cycling in pigeonpea-based cropping systems.

There are studies to prioritize desirable canopy traits for pigeonpea in the form of plant/crop ideotypes; these are intended to guide breeding efforts for particular environments. Physiological information on SD pigeonpea is being assembled in the form of crop models, which allow synthesis of current knowledge, understanding of feedback mechanisms, and prediction of crop performance in particular environments. These studies are linked to agroclimatology studies, which now use geographic information systems (GIS) methodology. Attempts are continuing to unravel the often complex genotype x environment (G x E) interactions in pigeonpea. Success would depend on a better understanding of temperature x photoperiod effects on crop growth and phenology; the Kenya altitude transect is playing a useful role in this regard.

Pigeonpea is included as a component of various cropping systems studies at IAC aimed at better understanding the principles involved.

Entomology

ICRISAT entomologists have collaborated with their colleagues in NARS, other international agricultural research centers, and nongovernmental organizations in pest management research. Research on the following pests has been undertaken at ICRISAT:

- *Helicoverpa armigera,* which is widespread in Asia and Africa (a related species, *Heliothis virescens,* is important in Latin America and the Caribbean);
- *Melanagromyza obtusa,* which is reported from both Asia and Africa;

- *Maruca testulalis,* an important and widespread pest of many legumes (especially determinate, short-duration pigeonpea) in Asia, Africa, Latin America, and the Caribbean;
- Pod-sucking bugs—several genera (*Clavigralla, Nezara, Anoplocnemis, Riptortus)* are important, and in some genera more than one species is reported as a pest;
- Other pod-boring Lepidoptera—*Etiella, Exelastis, Lampides;*
- Pod wasp (*Tanaostigmodes cajaninae*).

The majority of our research has been on the first two species. Future efforts in ICRISAT's MTP will be directed at these two pests, along with *M. testulalis.*

Ecological studies. Very detailed studies of the biology and ecology (growth, development, fecundity, natural enemies, and alternative host plants) of these pests have been conducted. Distribution and abundance patterns, and their dependence on weather, agronomic, and plant morphological factors, have been studied.

We are interested in measuring both insect population levels and pest-related losses. ICRISAT, in collaboration with NARS and mentor institutions, has developed trapping and monitoring strategies and equipment, particularly pheromone traps, for the key pests. More recent studies focus on interactions across several trophic levels (plant-pest-natural enemy) in pigeonpea/sorghum and pigeonpea/cotton cropping systems. Future research plans include the modelling of these multi-trophic level interactions.

Host-plant resistance. The major effort has gone into the development of cultivars resistant to *Helicoverpa* and *Melanagromyza.* Several medium-duration, *Helicoverpa*-resistant cultivars have been released in India. Other ICRISAT lines have served as parents in national breeding programs. Several longer duration lines with resistance to *Melanagromyza* have also been identified. The mechanisms for resistance to these pests are not known but are currently being investigated.

Control methods. The role and impact of natural enemies (parasites, predators, and pathogens) has also been investigated. In general, the *Helicoverpa* natural enemy fauna is less diverse and less effective on pigeonpea than on other *Helicoverpa* host plants. Egg parasites active against this pest on other crops do not parasitize eggs on pigeonpea. The reasons for this are not clear. A number of parasites of pod fly, *Maruca,* and several of the pod-sucking bugs have been identified in India.

Much work has been done on the effect of intercropping pigeonpea With cereals on *Helicoverpa* incidence/damage. In traditional Indian intercropping systems, where sorghum is harvested before the intercropped pigeonpea flowers, neither damage levels nor pest populations are reduced on pigeonpea. We are currently investigating the possibility of improving natural control by using short-duration pigeonpea, which flowers before sorghum does. In the area of chemical control (which has been extensively studied by the national programs), notable ICRISAT successes include the development of spray equipment technology, particularly Ultra Low Volume (ULV) sprayers. In addition, ICRISAT is collaborating with the Natural Resources Institute

(NRI) of UK and the Indian national program to study insecticide resistance in *Helicoverpa* and develop strategies to manage resistant populations, which have lately become a serious problem in India.

Integrated pest management. On-station investigations involve the use of two or more components to control pest populations. The effectiveness of the components and their interactions are being studied. In addition, we collaborate with NARS and nongovernmental organizations to test and evaluate different pest management strategies on-farm. These studies involve extensive farmer participation, e.g., their perceptions of constraints and pest management strategies, and preferences for particular strategies.

Pathology

Fusarium wilt, sterility mosaic (SM), and phytophthora blight (PB) are the important diseases of pigeonpea in South and Southeast Asia. Wilt, powdery mildew (PM), and cercospora leaf spot (CLS) are important in eastern and southern Africa; and witches' broom (WB) in the Caribbean and central American region. At IAC, research has focused on wilt, SM, and PB (which occur in Asia), rather than on the other diseases. The work on wilt has also benefitted NARS in eastern and southern Africa. There has been negligible work on WB because of funding constraints and reasons of geography. However, a collaborative project with the University of Florida, USA, on etiology, epidemiology, and management of WB has been in operation since 1991. ICRISAT's primary approach to disease management has been the development of resistant cultivars. Limited studies were also carried out to understand the effects of cultural practices such as intercropping and rotations on the diseases, with the aim of developing integrated disease management practices.

Work on PM and CLS has been very limited. These diseases, though widely prevalent, are not serious in the long-duration landraces in Africa; however, their occurrence was severe on the short- and medium-duration lines introduced from IAC.

ICRISAT's work on pigeonpea wilt in Africa has been in the areas of disease survey, supply of wilt-resistant materials, investigation of pathogenic variability in *Fusarium udum,* and the development of facilities for screening for resistance to wilt, PM, and CLS. Several lines supplied by IAC were found resistant to wilt in Kenya and Malawi; e.g., ICPs 8864, 9134, 9145, 9155, 9156, 9177,10957,10960,11299, and 12738. ICP 9145 has been released in Malawi, resulting in a considerable reduction in wilt incidence in farmers' fields. Preliminary studies on variability in *F. udum* in Kenya and Malawi indicate that the fungus is variable. The work at IAC with isolates from India indicates that the fungus has two distinct strains.

There appears to be some relationship between pigeonpea phenology and susceptibility to foliar diseases such as PM and CLS; the crop seems to be more susceptible during the reproductive phase than in the vegetative phase. The local landraces, by being late and flowering in dry weather, generally escape from these diseases. Hence, attempts to reduce crop duration must take this aspect into consideration. But the

African landraces also seem to have better resistance to PM and CLS than the Indian materials. ICPs 9150, 13107, 13156, and 13232 originating from Africa showed resistance to PM at IAC under natural epiphytotic conditions during the 1992/93 season.

Some of the other recent wilt studies carried out at IAC may be relevant to Africa:

- The relationship between wilt incidence and yield loss was found to be linear;
- There was a negative relationship between wilt incidence and monthly rainfall during the crop season;
- *Fusarium udum* population in the soil at sowing in June was negatively correlated with the preceding summer's rainfall;
- Final wilt incidence is strongly correlated with initial *F. udum* population in the soil (at sowing). Moisture and temperature have minor effects;
- The threshold level of *F. udum* populations in soil at sowing for 20% wilt incidence in a susceptible cultivar was found to be 830-920 cfu g^{-1} soil (cfu = colony farming units);
- Pigeonpea plants wilted when 50% of the main stem was colonized by *F.udum;*
- Sorghum intercropping reduced wilt incidence in both Vertisols and Alfisols;
- Castor rotation reduced the *F. udum* population in Alfisols to below threshold level (<1000 cfu g^{-1} soil);
- Pathogen population in the root zone was lower in resistant genotypes than in susceptible types. Root exudates from resistant cultivars were found to inhibit *F. udum;*
- Optimum temperatures for pathogen development and wilt incidence were found to be 25-30°C;
- Susceptibility to wilt decreased with age of the plant; and infections after 6 weeks did not cause death;
- *Fusarium udum* inoculum at 75 cm and deeper was ineffective in causing wilt;
- Presently available pigeonpea lines, when grown as perennials, show resistance to wilt for only two seasons.

Future inputs from IAC to pigeonpea pathology research in Africa are expected to be:

- Evaluation of early segregating materials of crosses made for Africa for wilt resistance in wilt-sick plots at IAC;
- Assistance in a *F. udum* pathogenic variability study;
- Understanding the influence of cropping systems on *F. udum* and wilt incidence.

Further Information

For more detailed information the reader is referred to recent ICRISAT Annual Reports, annual and quarterly reports of ICRISAT's Legumes, Resource Management, and Genetic Resources Programs, SAT News (which includes lists of recent publications), International Pigeonpea Newsletter, The Pigeonpea' (1990, Nene, Y.L., Hall, S.D., and Sheila, V.K., eds., CAB International, UK), ICRISAT Publications Catalog, and ICRISAT In Print.

Pigeonpea Diseases in Eastern and Southern Africa

Pala Subrahmanyam[1]

Introduction

Diseases are a major constraint to pigeonpea production in eastern and southern Africa. A large number of fungal, bacterial, viral, and nematode diseases have been reported from the region (Table 1), but only a few of them are economically important on a regional basis. These include fusarium wilt (*Fusarium udum*), cercospora leaf spot (*Cercospora cajani*), and powdery mildew (*Oidiopsis taurica*).

Fusarium Wilt

Fusarium wilt is the most serious disease in all major pigeonpea-producing countries in the region. Surveys carried out in 1980 estimated wilt incidence to be 60% in Kenya, 36% in Malawi, and 24% in Tanzania (Kannaiyan et al. 1984). The annual loss due to fusarium wilt alone in these countries was estimated at US$ 5 million (Kannaiyan et al. 1984).

Such cultural practices as intercropping or mixed cropping with sorghum; rotation with tobacco or sorghum; and 1-2 years of fallowing have been reported to be effective in reducing the incidence of wilt (Reddy et al. 1990b).

Breeding for wilt resistance is in progress in Kenya, Malawi, and Tanzania. Wilt-sick nurseries have been developed as described by Nene et al. (1981) and screening of germplasm and breeding lines is in progress. Collaborative screening of pigeonpea genotypes by ICRISAT and NARS in India and eastern and southern Africa has resulted in the identification of several sources of wilt resistance in a wide range of genotypes in Kenya (ICPs 8864, 9145, 9155, 10957, and 10960) and Malawi (ICPs 9134, 9142, 9145, 9156, 9177, 10960, 11299, and 12738) (Reddy et al. 1990a). Two lines, ICP 9145 and ICP 10960, showed wilt resistance in both Kenya and Malawi. Although a few lines resistant to wilt at ICRISAT Asia Center (IAC) showed resistance in Kenya and Malawi, many other lines resistant at IAC showed susceptibility in these countries. This could be due to differences in climatic factors or due to the occurrence of virulent pathoty pes in Kenya and Malawi.

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Table 1. Occurrence and relative importance of pigeonpea diseases in selected countries in southern and eastern Africa.

Disease (causal organism)	Disease severity[1]					
	Kenya	Malawi	Tanzania	Uganda	Zambia	Ethiopia
Fusarium wilt (*Fusarium udum*)	+ +	+ + +	+ +	+ +	+ + +	
Root and stem rot (*Macrophomina phaseolina*)		+		+	+	
Root and stem canker (M. *phaseolina*)		+				
Root rot (*Rhizoctonia solani*)				+	+	
Stem canker (*Phoma sorghina, Phomopsis cajani, Cercospora canescens, Colletotrichum crassipes*)					+	
Bacterial stem canker (*Xanthomonas campestris* pv *cajani*)		+			+	+
Collar rot (*Sclerotium rolfsii*)					+	
Damping-off/root rot (*Dendrochium gigasporum*)	+					
Cercospora leaf spot (*Cercospora cajani*)	+ + +	+ +	+ +	+ +	+ + +	
Powdery mildew (*Oidiopsis taurica*)	+ +	+ +	+ +	+ +	+ + +	+
Rust (*Uredo cajani*)	+		+	+		
Phoma leaf spot (*Phoma* sp)		+			+	
Wet rot (*Rhizoctonia solani*)					+	
Cercoseptoria leaf spot (*Cercoseptoria cajanicola*)					+	
Phytophthora blight (*Phytophthora drechsleri* f. sp. *cajani*)	+					
Sclerotinia blight (*Sclerotinia* sp)					+	
Halo blight (*Pseudomonas syringae* pv *phaseolicola*)		+			+	+
Macrophoma leaf spot (*Macrophoma cajanicola*)			+			
Leaf blight/spot (*Alternaria* sp)	+	+			+	
Web blight (*Rhizoctonia solani*)					+	
Leaf spot (*Phaeoisariopsis griseola*)					+	
Leaf blight (*Cladosporium oxysporum*)					+	
Cowpea mosaic (virus?)	+					
Mosaic/ring spot (virus?)		+			+	
Witches' broom (mycoplasma-like organism)					+	
Root-knot (*Meloidogyne* spp)	+	+		+	+	

1. + present, but not economically important; + + serious in some parts of the country; + + + serious and destructive in all major pigeonpea-producing areas of the country.

In Malawi, the wilt-resistant cultivar ICP 9145 was released for cultivation in 1986/87 and is now grown on 15-20% of the area under pigeonpea in Malawi. Wilt incidence in 1980 was estimated to be 36% (Kannaiyan et al. 1984). However, during a 1991 disease survey by Reddy et al. (1992), disease incidence was only 6.3%. The reduced incidence was attributed to the introduction of ICP 9145 (Subrahmanyam et al. 1992).

Cercospora Leaf Spot

After wilt, cercospora leaf spot is probably the most important disease of pigeonpea in the region. The disease is widely distributed and causes considerable yield losses. In Kenya, it occurs in epidemic proportions in high-altitude areas in years when rainfall is heavy and the rainy season extended (Songa et al. 1991). Yield losses of up to 85% have been recorded in some years (Onim 1980). In Malawi, the disease is prevalent in all major pigeonpea-growing areas, especially those with high humidity. Subrahmanyam (unpublished) estimated the mean yield loss in short-duration genotypes due to combined attacks of cercospora leaf spot and powdery mildew in Malawi to be 32% in 1992/93. The disease is not serious in dry years (e.g., during the 1991/92 season).

Crop rotation may be useful in reducing the sources of primary inoculum. Fungicides such as benomyl and mancozeb have been shown to be effective in reducing disease severity and increasing yield (Onim 1980).

Onim and Rubaihayo (1976) reported a number of sources from Kenya having a high degree of resistance to cercospora leaf spot (UCs 796/1, 2113/1, 2515/2, and 2568/1). Recently, several sources of resistance have been identified in genotypes belonging to different maturity groups in Kenya: KCCs 50/3, 60/8,119/6, and 423/13 (short-duration); KCCs 81/3/1, 576/3, 657/1, and 777, and ICP 13081 (medium-duration); and KCCs 66, 605, and 666, and ALPL 6-2 (long-duration) (Songa 1991).

Powdery Mildew

Powdery mildew is a serious disease in parts of Malawi, Kenya, Zambia, Tanzania, and Uganda, especially during wet years. Combined attacks of powdery mildew and cercospora leaf spot cause extensive damage to foliage.

Reddy et al. (1993) reported a high degree of resistance to powdery mildew in some Kenyan germplasm lines (ICPs 9150, 13107, 13156, and 13232).

Future Research Needs

With the exception of Kenya (Kannaiyan et al. 1984, Songa et al. 1991), Malawi (Kannaiyan et al 1984, Reddy et al. 1992), Zambia (Kannaiyan and Haciwa 1990), Uganda, and Tanzania, there is very little information available on the occurrence and relative importance of various diseases of pigeonpea in eastern and southern Africa. There is a need, therefore, for systematic disease surveys in many countries of the region.

Although the incidence of wilt can be effectively reduced by adopting such cultural practices as crop rotation and intercropping/mixed cropping, these practices have limitations at farm level because of small landholdings and differential crop priorities. Chemical control of cercospora leaf spot and powdery mildew is effective, but may not be economically feasible for smallholder farmers. Hence, breeding for resistance to these diseases is decidedly the most effective strategy.

Breeding for disease resistance has so far largely focused on wilt; very little has been done on other diseases. Excellent sources of resistance to cercospora leaf spot and powdery mildew are now available. These genotypes should be evaluated for stability of resistance, and for grain yield and other agronomic and commercial attributes. If they meet local agronomic and commercial demands, they can be released to farmers for cultivation (ICP 9145 in Malawi is a good example). If they are not suitable for release, they should be used as sources of resistance in breeding programs.

Progress in breeding for resistance will be faster if reliable sick plots are developed. Sick plots have been developed in Kenya, Malawi, and Tanzania, but not so far in other countries in the region.

Research should be initiated for the identification of pathotypes of *F. udum,* if they exist, since it is important to develop genotypes with stable and durable resistance to the disease.

Combining resistances to wilt, cercospora leaf spot, and powdery mildew should prove beneficial in reducing the losses due to these diseases in southern and eastern Africa.

References

Kannaiyan, J. and Haciwa, H.C. 1990. Diseases of pigeonpea in Zambia. International Pigeonpea Newsletter 12:22-23.

Kannaiyan, J., Nene, Y.L., Reddy, M.V., Ryan, J.G., and Raju, T.N. 1984. Prevalence of pigeonpea diseases and associated crop losses in Asia, Africa and the Americas. Tropical Pest Management 30:62-71.

Nene, Y.L., Kannaiyan, J., and Reddy, M.V. 1981. Pigeonpea diseases: resistance-screening techniques. Information Bulletin no. 9. Patancheru, A. P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 14 pp.

Onim, J.F.M. 1980. Foliar fungicides for the control of *Mycovellosiella cajani* causing leaf spot of pigeonpea. Indian Journal of Agricultural Sciences 50:615-619.

Onim, J.F.M. and Rubaihayo, P.R. 1976. Screening pigeonpea for resistance to *Mycovellosiella cajani.* SABRAO Journal 8:121-125.

Reddy, M.V., Nene, Y.L., Kannaiyan, J., Raju, T.N., Saka, V.W., Daudi, A.T., Songa, W.P., and Omanga, P. 1990a. Pigeonpea lines resistant to wilt in Kenya and Malawi. International Pigeonpea Newsletter 12:25-26.

Reddy, M.V., Raju, T.N., Remanandan, P., and Mengesha, M.H. 1993. Is African pigeonpea germplasm a source of resistance to powdery mildew? International Pigeonpea Newsletter 17:27-28.

Reddy, M.V., Sharma, S.B., and Nene, Y.L. 1990b. Pigeonpea: disease management. Pages 303-347 *in* The Pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds.). Wallingford, Oxon, UK: CAB International.

Reddy, M.V., Subrahmanyam, P., Likoswe, A.A., Saka, V.W., and Msuku, W.A.B. 1992. Survey of pigeonpea diseases in Malawi. International Pigeonpea Newsletter 15:24-25.

Songa, W.A. 1991. Evaluation of pigeonpeas for cercospora leaf spot resistance in Kenya. International Pigeonpea Newsletter 13:24-26.

Songa, W.A., Omanga, P., and Reddy, M.V. 1991. Survey of pigeonpea wilt and other diseases in Machakos and Kitui districts of Kenya. International Pigeonpea Newsletter 14:25-26.

Subrahmanyam, P., Reddy, M.V., Likoswe, A.A., Saka, V.W., and Msuku, W.A.B. 1992. Diseases of pigeonpea in Malawi. Pages 56-57 *in* Pigeonpea in eastern and southern Africa: summary proceedings of the Launching Meetings for the African Development Bank/ICRISAT Collaborative Pigeonpea Project for Eastern and Southern Africa, 17-18 Mar, Nairobi, Kenya and 30-31 Mar 1992, Lilongwe, Malawi (Silim, S.N., Tuwafe, S., and McGaw, E.M., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Status of Pigeonpea Research in Kenya, and Future Prospects

P.M. Kimani[1], P.A. Omanga[2], and S.N. Silim[3]

Introduction

Pigeonpea (*Cajanus cajan* L. Millsp.) is the major grain legume crop in the semi-arid areas which occupy 82% of Kenya's landmass. The main production areas are Machakos, Makueni, Kitui, lower Embu, Meru, and Tharaka-Nithi districts in Eastern Province; the drier parts of Kirinyaga, Murang'a, and Kiambu districts in Central Province, and parts of Coast Province. It is especially valued in these areas because it is drought-tolerant and requires very few inputs. However, yields are low (0.40-0.60 t ha^{-1}) (Mbatia and Kimani 1990). The crop is grown rainfed, and normally intercropped with maize, sorghum, cotton, beans, and cowpeas. Fertilizers are rarely used; weeding is done twice or thrice during the 9- to 10-month growing period.

Constraints to Productivity

The low productivity is attributed to several reasons, which are discussed in detail by Kimani (1987). They include:

- Low-yielding cultivars. Most farmers grow tall, long-duration (9-10 months) landraces;
- Lack of quality seed;
- Diseases—mainly fusarium wilt (*Fusarium udurn*) and leaf spot *(Mycovellosiella cajani)* in particular, and to a lesser extent powdery mildew (*Leveillula taurica);*
- Insect pests—pod borers (*Helicoverpa armigera, Maruca testulalis),* pod fly (*Melanagromyza* spp), and pod-sucking bugs (*Clavigralla tomentosicollis, Nezara viridula*). Less important, but still serious, are thrips *(Megalurothrips* spp), blister beetles (M*ylabris* spp), and the pollen beetle (*Coryana apicicornis);*
- Poor production practices, e.g., low plant densities, absence of manure and other soil amendments, insufficient weeding, and insufficient/inappropriate use of fungicides and herbicides;

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- Environmental factors (frequent droughts; low-nutrient, easily erodible soils with poor water-holding capacity);
- Socioeconomic factors, e.g., lack of roads and marketing infrastructure, exploitation by middlemen.

Objectives

Pigeonpea research in Kenya started in 1977 at the University of Nairobi and in 1980 at the National Dryland Farming Research Centre at Katumani. The objectives of the projects were to:

- Develop short-duration, high-yielding varieties with acceptable seed characters and resistance to drought, major diseases (especially fusarium wilt), and pests;
- Develop improved production practices;
- Identify the socioeconomic constraints to production, and devise approaches to overcome them;
- Develop and implement a sustainable seed scheme;
- Transfer technologies to farmers.

Considerable progress has been made on various aspects, as summarized below.

Breeding Research

The first short-duration (5 months) cultivar, NPP 670, was released in 1983. It was developed through hybridization and selection from crosses between short-duration, small-seeded ICRISAT genotypes and long-duration, large-seeded local landraces (Kimani 1990).

After the release of NPP 670 it was realized that early maturity was important to farmers, and subsequent breeding efforts focused on short-duration cultivars. However, since these may not fully utilize the entire growing season, medium- and long-duration cultivars were also developed. During the period 1983-93, cultivars of various maturity groups were found to be promising on the basis of multilocational trials in Kenya (Tables 1-3).

Short and extra short duration cultivars (about 70 days to flower, 120 days to maturity) were introduced from ICRISAT and have shown wide adaptation under Kenyan conditions, with yields of up to 3 t ha^{-1} (Ornanga et al. 1992). Promising cultivars in this group include ICPLs 87, 151, 8316, and 87102. These cultivars are small-seeded and are not popular for consumption as whole grain, but can be utilized as *dhal,* for which seed color and size are not critical.

The short-duration cultivars are widely adapted, but perform best at medium altitude (600-1500 m) locations with warmer temperatures (mean 26°C). Such areas include lower Machakos, Kitui, Meru, and Embu. With good management, grain yields of 1.2-2.5 t ha^{-1} can be obtained. They can be sown in Oct/Nov, harvested

Table 1. Promising short-duration pigeon pea lines developed in Kenya.

Line	Days to maturity	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	100-seed mass (g)	Yield (t ha^{-1})	Wilt rating[1]
KO-25/2	152	107	71	4.5	15.6	1.82	R
K 0 46	168	110	74	4.6	14.1	1.63	MR
KO 59/1	160	108	69	4.8	15.0	1.55	T
K 0 71/2	153	106	87	4.5	14.5	2.11	MR
KO 78	154	120	76	4.6	13.5	1.73	T
KO 120	157	97	75	4.8	14.1	1.82	T
Kat 60/8	160	-	-	-	14.4	1.52	-
Kat 50/3	160	-	-	-	14.7	1.58	-
IIRA	140	-	-	-	11.9	1.47	-
K 0 237	163	114	72	4.4	14.2	1.91	R
KO 420	160	107	72	4.5	14.5	2.11	T
KZ 48/2	164	91	108	4.7	15.4	1.73	R
KZ 56	162	112	52	4.5	15.6	2.35	T
KZ 63	162	101	73	4.6	14.7	1.43	R
KB 38/1	161	117	85	4.3	16.0	2.84	R
TK-21/1	158	96	67	4.4	14.6	1.85	R
TK 46/2	162	97	119	4.8	16.0	2.47	T
NPP 670	155	83	28	4.1	19.3	1.30	MR

1. R = Resistant, MR = Moderately resistant, T = Tolerant, S = susceptible, - = Not tested.
Sources: Kimani (1993), Omanga et al. (1990, 1992).

Table 2. Promising medium-duration pigeonpea lines developed in Kenya.

Line	Days to maturity	Plant height (cm)	Pods plant^{-1}	Seeds pod"^{1}	100-seed mass (g)	Yield (tha^{-1})	Wilt rating[1]
KO 170	174	104	189	4.7	16.0	2.96	R
KZ 3	170	79	171	4.8	14.0	2.42	T
KZ 21/2	172	83	93	4.7	14.3	1.77	MR
Kat 777	166	-	-	-	16.9	1.42	-
Kat 657/1	190	-	-	-	15.7	1.66	-
Kat 81/3/3	191	-	-	-	15.3	1.53	-
NPP 671/1	183	167	103	4.6	14.8	1.38	T
NPP 671/6	177	165	121	4.2	17.9	2.61	R
NPP 673/1	197	200	108	4.4	17.0	1.20	MR
NPP 675/2	188	132	64	4.7	16.1	3.16	T
NPP 675/4	189	110	119	4.7	16.1	2.59	T
NPP 675/6	177	162	85	4.9	16.2	1.57	R
NPP 688/2	189	202	91	5.0	21.2	2.34	T
NPP 695/1	189	162	110	4.4	19.2	1.39	T
NPP 695/2	189	156	129	5.2	16.8	3.21	MR
NPP 674/1	177	211	80	4.5	18.3	2.48	R

Continued

Table 2. *Continued*

Line	Days to maturity	Plant height (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	100-seed mass (g)	Yield ($t\ ha^{-1}$)	Wilt $rating^{-1}$
NPP 691/1	177	129	121	4.2	18.7	1.27	R
NPP 691/2	177	244	84	4.3	14.3	1.59	MR
NPP 691/3	174	108	94	5.5	16.1	2.20	MR
NPP 691/4	184	120	141	4.1	18.2	3.54	T
NPP 693/3	174	123	60	4.1	15.0	1.98	MR
NPP 699/1	197	142	102	4.4	18.6	2.63	R
NPP 699/2	188	136	100	4.5	18.7	3.59	R
Munaa	198	214	88	4.7	20.0	3.23	S

1. R = Resistant, MR = Moderately resistant, T = Tolerant, - = Not tested.

Sources: Kimani (1993), Omanga et al. (1990).

Table 3. Promising long-duration pigeonpea lines in Kenya.

Line	Days to maturity	Plant height (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	100-seed mass (g)	Yield ($t\ ha^{-1}$)	Wilt rating[1]
NPP 671	210	156	93	4.0	16.4	1.27	T
NPP 673/3	216	167	64	4.9	17.8	1.52	T
NPP 688/3	211	180	62	5.0	19.5	1.49	T
NPP 688/4	210	183	74	5.2	18.8	1.92	T
NPP 688/5	212	247	44	5.0	20.7	1.71	MR
NPP 707/1	209	172	76	5.2	16.5	2.35	MR
NPP 707/2	209	210	68	4.8	16.1	1.48	MR
Kat 788	235	-	-	-	17.2	1.33	-
Kat 2	223	-	-	-	14.3	2.20	-
Kat E31/4	238	-	-	-	18.8	2.11	-
Kat E9/6	227	-	-	-	16.9	2.02	-
Kat 590	220	-	-	-	13.6	2.11	-
Kioko	224	188	80	5.0	19.7	2.26	MR
Katheka	233	187	141	4.7	22.2	1.26	-

1. R = Resistant, MR = Moderately resistant, T = Tolerant, - = Not tested.

Sources: Kimani (1993), Omanga et al. (1990).

before the onset of the long rains in Mar/Apr and ratooned with a second harvest obtained in Jul/Aug, The crop can also be sown in Apr and harvested before Sep.

The medium- and long-duration varieties are intended for areas with bimodal rainfall where the long rains are less reliable. They are sown in Oct/Nov with the onset of the short rains, and harvested after the long rains. The medium-duration lines are more adapted to medium/high elevations (900-1800 m) with 600-1500 mm annual rainfall, and can be grown in mixed or intercropped systems. They have a yield potential of up to 3.5 t ha^{-1}. Similarly, the long-duration cultivars are better adapted to locations at elevations of 1000-1500 m, with 700-1000 mm annual rainfall. They have a yield potential of about 2.5 t ha^{-1}.

Agronomy Research

Until recently, there was little work done on the agronomy of pigeonpea in Kenya. It was evident that the potential of improved varieties could be realized only when appropriate cultural practices were developed and adopted. Agronomic experiments on spacing, rhizobial inoculation, weeding requirements, intercropping, fertilizer requirements, and related physiological aspects were initiated in 1984 (Kimani 1990, 1993). The experiments showed that grain yield increased significantly in short-duration cultivars as plant population increased from 10 000 to 114 000 plants ha^{-1}. Although the highest yield was obtained at 114 000 plants ha^{-1}, it is suggested that this density is higher than optimal because the crop is grown in drought-prone areas on nutrient-poor soils. Presently the recommendation is 44 440 plants ha^{-1} (spaced at 75 x 30 cm) in pure stands.

Studies conducted in Kenya with four *Rhizobium* strains have shown that inoculation increases nodulation and grain yield. Both phosphate and rhizobia increased grain yield when applied individually; in combination, their effect was more pronounced.

The low yields in eastern Africa have been attributed partly to deficiencies in soil nutrients (although farmers routinely use animal manures and sometimes chemical fertilizers). Little research has been conducted on the nutrition of pigeonpea. However, studies have been conducted in Thika, Machakos, and Kiboko on the effect of urea, manure, and phosphate application on grain yield. The results demonstrate that yields can be substantially improved by soil amendments, especially where soils are deficient in nutrients.

Studies on weeding frequency showed that the longer the weeds are allowed to grow with pigeonpea, the higher the reduction in grain yield. The results indicated that the critical weed competition period was between 3 and 9 weeks after sowing. Weeding should therefore be done within 3-4 weeks after germination, and again before the ninth week. Subsequent weedings may be required depending on weed growth and the rainfall pattern. Omanga et al. (1992) recommend the use of pre-emergence herbicides for large commercial farms.

In Kenya, pigeonpea is predominantly intercropped with maize, sorghum, beans, cowpeas, and cotton. Studies have shown that intercropping is 24-75% more productive than monocropping. Among the maize-pigeonpea combinations, alternating two rows of maize with two rows of pigeonpea gave the highest total yield. One row of maize (two plants per hill) between two rows of pigeonpea gave the highest land equivalent ratios. In the sorghum-pigeonpea intercrop, a combination of two rows of pigeonpea with two rows of sorghum gave the highest yield and land equivalent ratios.

Diseases

Research has focused on fusarium wilt and leaf spot. The pathogens responsible have been isolated and characterized (Okiror 1986, Njoya et al. 1990). Screening techniques have been developed and evaluated under both greenhouse and field conditions. The genetics of wilt resistance have been studied (Kimani 1990). Genotypes resistant to these diseases have been identified (Reddy 1990), and in the case of wilt, resistance incorporated into promising breeding lines (Kimani 1993). However, due to variation in the wilt pathogen, resistant genotypes from one area may not be resistant in another.

Insect Pests

The major pests of pigeonpea in Kenya have been identified, and the nature of damage quantified (Kimani 1990, Omanga et al. 1990, Mugo 1992). Methods of chemical control have also been studied. No resistant varieties have been identified. However, indeterminate types seem to be more tolerant than determinate types. Detailed studies are needed on the biology and seasonal distribution of these pests.

Socioeconomic Studies

Two surveys were conducted in 1987 and 1989 to identify the socioeconomic constraints to pigeonpea production in Kenya, and determine the reactions of farmers to recently-introduced short-duration cultivars (Mbatia and Kimani 1990, 1992). The surveys identified a number of constraints: lack of labor and/or capital for optimal management, poor information dissemination, poor marketing infrastructure, unremunerative pricing, and traditional preferences.

Seed Production

Unavailability of certified seed is a major constraint to the adoption of improved cultivars (Kimani and Mbatia 1993). Commercial seed companies do not produce certified seed due to fluctuations in demand in semi-arid areas. Pilot seed multiplication and dissemination schemes initiated by the pigeonpea improvement program were effective, but could not be sustained after the termination of the project. Better marketing organization and infrastructure development will probably stimulate demand for quality seed.

References

Kimani, P.M. 1987. Pigeonpea breeding in Kenya: Objectives and methods. Pages 5-28 *in* Proceedings of Pigeonpea Scientists' Meet, 2-5 Jun 1987, Nairobi, Kenya.

Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Kimani, P.M. 1990. Pigeonpea improvement research in Kenya: an overview. Pages 108-117 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Kimani, P.M. 1993. Pigeonpea improvement in Kenya: Final report, phase IV. Ottawa, Canada: International Development Research Centre. 22 pp.

Kimani, P.M. and Mbatia, O.L.E. 1993. Seed production and distribution mechanisms. Case study for pigeonpea in Kenya. Pages 23-47 *in* Seed production mechanisms (Thomas, N. and Mateo, N., eds.). Ottawa, Canada: International Development Research Centre.

Mbatia, O.L.E. and Kimani, P.M. 1990. Survey of production systems, marketing and utilization of pigeonpea in Kenya. Pages 118-120 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Mbatia, O.L.E. and Kimani, P.M. 1992. Pigeonpea marketing in Kenya. Pages 57-62 *in* Proceedings of the Consultative Group Meeting on production and agroprocessing of sorghum and pigeonpea in Kenya, Nairobi, Kenya, 18-19 Sep 1991 (Laxman Singh, Mukuru, S.Z., Silim, S.N., and King, S.B. (eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes EARCAL Program, International Crops Research Institute for the Semi-Arid Tropics, and Kenya Agricultural Research Institute.

Mugo, H.M. 1992. Podborer insects attacking pigeonpea at flowering and post-flowering stages and their impact on yield in Kenya. M.Sc. thesis, University of Nairobi, Kenya.

Njoya, E.W., Kimani, P.M., Mwang'ombe, A.W., and Shankar, M. 1990. Reaction of pigeonpea genotypes to a leaf spot disease caused by *Mycovellosiella cajani.* Pages 155-161 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Okiror, M.A. 1986. Breeding for resistance to fusarium wilt of pigeonpea *(Cajanus cajan* L. Millsp.) in Kenya. Ph.D. thesis, University of Nairobi, Kenya.

Omanga, P.GA., Shakoor, A., and Siambi, M. 1990. Pigeonpea production and research in Kenya. Pages 101-107 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P. and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Omanga, P.G.A., Siambi, M., Shakoor, A., and Wafula, B.M. 1992. Improved pigeonpea cultivars and production technology. Pages 29-35 *in* Proceedings of the Consultative Group Meeting on production and agroprocessing of sorghum and pigeonpea in Kenya, 18-19 Sep 1991 (Laxman Singh, Mukuru, S.Z., Silim, S.N., and King, S.B., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics and Kenya Agricultural Research Institute.

Reddy, M.V. 1990. Disease problems of pigeonpea in Eastern Africa—Progress and future research needs. Pages 60-64 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N. Ariyanayagam, R.P., and Reddy, M.V., eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Pigeonpea Pathology Research in Kenya: Progress and Future Research Strategies

W. Songa[1] and S.B. King[2]

Introduction

Diseases of pigeonpea are increasing in eastern and southern Africa, as a few improved (but susceptible, especially in epidemic years) cultivars are grown over large areas. Surveys carried out by Kannaiyan et al. (1984) and Songa (1991a) showed that fusarium wilt (*Fusarium udum* Butler), cercospora leaf spot (*Cercospora cajani* Hennings = perfect stage *Mycovellosiella cajani* (Henn.) Rangel ex Trotter), and powdery mildew (*Oidiopsis taurica* (Lev.) Salmon), in that order, were the most important diseases in Kenya (Table 1).

Table 1. Important pigeonpea diseases in Kenya.

Location	District	Wilt incidence (%)	Cercospora leaf spot incidence	Powdery mildew incidence
Katumani (wilt sick plot)	Machakos	55	Moderate	Low
Kimutwa	Machakos	8	Moderate	Low
Tawa	Machakos	10	High	Low
Sultan Hamud	Makueni	18	Moderate	Low
Makindu	Makueni	4	Low	Moderate
Masongaleni	Makueni	8	Low	Moderate
Kaani	Machakos	15	Low	Low
Masii	Machakos	17	Moderate	Low
Ikanga	Kitui	5	Low	Low
Matinyani	Kitui	6	Low	Low

Sources: Kannaiyan et al. 1984, Songa et al. 1991, Songa et al. unpublished.

Wilt incidence in farmers' fields has been reported to average about 10% in the major pigeonpea-growing districts of Machakos and Kitui (Songa 1991a). Cercospora leaf spot is prevalent at higher altitudes (1200-1700 m). It is usually severe

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during the long rains (Apr-Jun); yield losses of up to 80% have been reported (Onim 1980). Powdery mildew is sometimes severe during the long rains. In general, it is not of economic importance in the arid and semi-arid areas of Kenya, although periods highly favorable to the spread of the disease may result in 'shoot blight' (Allen 1983).

Disease Management

Host-plant resistance is the primary disease control strategy used by the Kenya Agricultural Research Institute (KARI), Katumani. Some high-yielding wilt-resistant cultivars have been developed (Omanga et al. 1991).

Screening for Resistance to Fusarium Wilt

The wilt-sick plot technique (Nene et al. 1981) is used to identify sources of resistance, and was found to be simple and effective at Katumani. Screening was started at Katumani in 1980, and over 700 lines have been screened so far. The evaluated lines include 200 from ICRISAT Asia Center (IAC), India, and over 500 local and improved pigeonpea lines from Katumani. Only 35 lines (7 from ICRISAT, 13 improved lines from Katumani, and 15 Kenyan landraces) showed consistent resistance for at least two seasons of testing (Table 2). Some ICRISAT lines, e.g., ICP 8858 and ICP 8862, which were reported resistant in India (Nene and Kannaiyan 1982), were found to be susceptible at Katumani. This may imply differences in the physiological races of this pathogen in Kenya, at least four of which may exist (Songa et al. unpublished). This study is being done in collaboration with the IAC pigeonpea program, which developed the screening technique and the set of differential lines.

It has now become necessary to shift the Katumani site to a new site on the station, as a result of station development activities. The new wilt-sick plot is being developed using inoculum from the old plot supplemented with inoculum from major pigeonpea production areas in Kenya. A second wilt-sick plot is being developed at Kiboko. This plot will complement the one at Katumani by having a generally warmer temperature (being 600 m lower), and a different pathogen population (collected only from fields near Kiboko).

The Kiboko sick plot has no previous history of pigeonpea cultivation. Infestation at Kiboko was achieved during 1992/93 in about 0.1 ha by adding chopped *F. udum* infected stem tissue to sowing furrows. Seed of susceptible varieties LRG 30 and ICP 2376 were sown in alternate rows 4 Nov 1992 at the beginning of the short rains. The frequency of plants with wilt symptoms was recorded five times at about 2-week intervals beginning on 4 Jan 1993, 2 months after sowing (Table 3). Plants with wilt symptoms were uprooted with each count and kept for later incorporation into the soil. There was a steady cumulative increase in wilt incidence for each variety from <10% at 2 months after sowing to >40% on 4 Mar 1993, 4 months after sowing. Another count of wilt incidence was made in randomly selected parts of the plot on

Table 2. Pigeonpea lines resistant to fusarium wilt in a sick plot at Katumani, Kenya.

	Wilted plants (%) in each season					
Line	1980/81	81/82	82/83	84/85	85/86	89/90
ICRISAT lines						
ICP 9145	0	0	-	-	-	-
ICP 9155	0	17	-	-	-	-
ICP 10960	0	9	-	12.5	-	-
ICP 10958	-	-	-	-	5.2	-
ICP 11299	-	8.3	10.0	-	-	-
ICP 11294	-	-	-	20.0	12.5	-
ICP 11292	-	14.2	-	-	0.0	-
ICP 2376[1]	-	43.0	47.6	-	-	100
Katumani improved lines						
KCC 423-18-9	-	5.8	-	-	-	12.0
KCC 423-17-4	-	8.0	-	13.5	-	-
KCC 423-78-12	-	11.1	-	-	-	15.4
KCC 423-109-1	-	20.0	-	18.2	-	-
KCC 423-47-1	-	18.1	-	9.5	-	-
KCC 423-109-2	-	14.2	-	-	-	17.0
KCC 423-75-4	-	20.0	-	7.3	-	-
KCC 423-27-2	-	-	17.6	13.3	-	-
KCC 423-43-15	-	-	20.0	9.4	-	-
KCC 423-60	-	-	19.5	12.5	-	-
KCC 466-14	-	0.0	-	11.4	-	-
KCC 83-3-3	-	14.2	-	-	-	16.3
KCC 657-1	-	-	-	-	9.4	17.4
KCC 423-21[1]	-	-	-	-	92.8	100
KCC 777[1]	-	-	-	-	100	80.6
Local landraces						
KCC 45-1	-	10.5	-	-	18.2	-
KCC 83-3	-	12.5	-	-	11.5	-
KCC 81-3	-	14.2	-	-	17.3	-
KCC 364-2	-	12.0	-	-	8.3	-
KCC 69	-	14.2	-	-	6.4	-
KCC 33	-	18.1	-	-	12.0	-
KCC 54	-	11.1	-	-	13.5	-
KCC 59	-	20.0	-	-	18.7	-
KCC 80	-	12.5	-	-	14.4	-
KCC 64	15.7	12.8	-	-	-	-
KCC 81	10.5	14.2	-	-	-	-
KCC 8	4.3	16.3	-	-	-	-
KCC 651	9.0	-	-	0.0	-	-
KCC 760	18.2	-	-	16.6	-	-
KCC 797	15.4	-	-	11.1	-	-

1. Susceptible control. - = Not tested

Source: Songa 1991b.

Table 3. Percentage cumulative incidence of *Fusarium udum* on two susceptible pigeonpea lines, 5 scorings at about 2-week intervals in *F. udum* infested soil, Kiboko, Kenya, 1992/93[1].

	Pigeonpea lines	
Scoring date	LRG 30	ICP 2376
4 Jan	9.4	6.5
19 Jan	14.1	15.1
3 Feb	20.6	22.5
18 Feb	31.2	33.7
4 Mar	43.0	46.9

1. Sown on 4 Nov 1992.

22 Apr; 47% incidence was recorded in LRG 30 and 55% in ICP 2376. These data suggest that wilt incidence in the plot exceeded 70% on a cumulative basis.

In 1993/94, a further 0.2 ha will be infested, and limited testing conducted on the portion already infested. We hope to eventually divide the field into two halves, sown to susceptible genotypes, and to test materials in alternate years to maintain high levels of soil inoculum.

Screening for Resistance to Cercospora Leaf Spot

Songa (1991a) evaluated 197 pigeonpea lines at Katumani for resistance to cercospora leaf spot, and reported moderate to low resistance. The lines with moderate resistance included KCC 657/1, ALPL 6-2, KCC 66, and KCC 666 (Table 4). Onim (1980) reported good control of this disease by foliar spraying with Benlate® and Dithane M 45®. However, the cost of these chemicals makes spraying uneconomical.

Future Research Strategies

Pigeonpea diseases have been reported to be of minor importance in the past in eastern Africa (Acland 1971, Rachie and Roberts 1974, Williams and Allen 1976). Recent surveys in the major pigeonpea-growing areas of Kenya show that wilt and cercospora leaf spot are diseases of economic concern (Kannaiyan et al. 1984, Songa et al. 1991). Crop rotation has been used in the past as a control method for wilt, but this is no longer possible due to the increased pressures on land. The emphasis for control of the pathogen will continue to be on the use of host-plant resistance.

There is now a need to screen for combined fusarium wilt and cercospora leaf spot resistances at Katumani. Cercospora leaf spot requires high humidity for development and spread. Irrigation facilities to supplement rainfall are now in place, with assistance from ICRISAT, at the new fusarium wilt-sick plot.

Table 4. Pigeonpea lines with moderate resistance to cercospora leaf spot at Katumani, Kenya, 1990.

Entry	Maturity group	Average score[1]
KCC 60/8	Short (136-150 days)	5.0
KCC 50/3	Short	5.0
KCC 423/13	Short	5.0
KCC 119/6	Short	5.0
KCC 657/1	Medium (150-180 days)	4.0
ICPL 13081	Medium	5.0
KCC 777	Medium	5.0
KCC 576/3	Medium	5.0
KCC 81/3/1	Medium	5.0
ALPL 6-2	Long (> 180 days)	4.5
KCC 605	Long	5.0
KCC 66	Long	4.5
KCC 666	Long	4.5

1. Score on a 1-9 scale, where 1 = no symptoms, 9 = severe symptoms.
Source: Songa 1991a.

We hope to initiate screening for powdery mildew resistance, as this disease was observed to be very severe in the Kiboko area of Makueni district during the long rains of 1992 (Songa et al. unpublished).

We plan to establish demonstration plots sown with the identified disease-resistant improved cultivars and with local landraces. The aim is to allow farmers to compare their performance (during farmers' field days), and thus encourage the adoption of disease-resistant cultivars.

References

Acland, J.D. 1971. Pigeonpea (*Cajanus cajan*). Pages 140-141 *in* East Africa Crops. London, UK: Longman.

Allen, D.J. 1983. The Pathology of Tropical Food Legumes. A Wiley-Interscience Publication.

Kannaiyan, J., Nene, Y.L., Reddy, M.V., Ryan, J.G., and Raju, T.N. 1984. Prevalence of pigeonpea diseases and associated crop losses in Asia, Africa, and the Americas. Tropical Pest Management 30(1):62-71.

Nene, Y.L., Kannaiyan, J., and Reddy, M.V. 1981. Pigeonpea diseases: resistance screening techniques. Information Bulletin no. 9. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 14 pp.

Nene, Y.L. and Kannaiyan, J. 1982. Screening pigeonpea for resistance to Fusarium Wilt. Plant Disease 66:306-307.

Omanga, P.A., Shakoor, A., and Siambi, M. 1991. Pigeonpea production and research in Kenya. Pages 101-107 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V. eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Onim, J.F.M. 1980. Foliar fungicides for the control of *Mycovellosiella cajani* causing the leaf spot of pigeonpea. Indian Journal of Agricultural Sciences 50:615-619.

Rachie, K.O. and Roberts, L.M. 1974. Grain legumes in the lowland tropics. Advances in Agronomy 26:1-32.

Songa, W.A. 1991a. Evaluation of pigeonpea for cercospora leaf spot resistance in Kenya. Pages 146-148 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya. (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V. eds.). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, International Crops Research Institute for the Semi-Arid Tropics.

Songa, W.A. 1991b. Screening pigeonpea for resistance to Fusarium wilt and other control strategies for this disease. Pages 131-135 *in* Recent Advances in KARI's Research Programmes: Proceedings of the 2nd KARI Annual Scientific Conference, 5-7 Sep 1990, Nairobi, Kenya. Nairobi, Kenya: Kenya Agricultural Research Institute.

Songa, W.A., Omanga, P., and Reddy, M.V. 1991. Survey of pigeonpea wilt and other diseases in Machakos and Kitui districts of Kenya. International Pigeonpea Newsletter 14:25-26.

Williams, F.J. and Allen, D.J. 1976. Pigeonpea diseases. Page 58 *in* Pathology grain legume training course, 16 Aug-26 Nov 1976. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Progress on Pigeonpea Research in Tanzania

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Introduction

Tanzania is divided into seven research zones: Eastern (EZ), Southern (SZ), Northern (NZ), Lake (LZ), Western (WZ), Central (CZ), and Southern Highland (SHZ) zones. Pigeonpea is grown throughout the country, but largely in the Southern and Northern zones. It is almost always an intercrop or mixed crop with cereals (mostly maize, sorghum, and millet). Some farmers also include such short-duration legumes as cowpea in pigeonpea-based cropping systems.

Productivity in Tanzania is very low, usually 0.30-0.50 t ha^{-1}. The low yields are due to a number of factors. These include insect pest damage on the long-duration landraces, diseases (especially fusarium wilt), low yield potential of landraces, terminal drought stress in some areas, and poor management factors (e.g., low plant densities).

Research Objectives

- Introduction of short-duration pigeonpea (with bold white seed) in some potential production areas;
- Evaluation of medium-duration lines as possible replacements for long-duration pigeonpea, e.g., in areas prone to terminal drought stress;
- Development of high-yielding long-duration pigeonpeas to improve existing cropping systems;
- Screening for resistance to fusarium wilt in all maturity groups;
- Development and propagation of superior agronomic practices;
- Conducting on-farm research to create awareness and transfer improved technologies to farmers.

Varietal evaluations

Extra Short Duration Pigeonpea International Trial. Twenty entries of extra short duration pigeonpeas received from ICRISAT Asia Center (IAC) were tested at Ifakara for adaptability, grain yield, and seed size and color. In the 1991/92 season

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similar trials were conducted at five locations and ICPLs 88001, 88009, and 89027 were among the highest yielders. Plant stand was very variable in the 1992/93 season. The highest yields were obtained from ICPL 90004 (1.17 t ha^{-1}) and ICPL 85010 (1.12 t ha^{-1}). ICPL 88001 (as in the 1991/92 trial) was the third highest yielder with 1.10 t ha^{-1}. The mean yield for the trial was 0.89 t ha^{-1}.

Short-duration Pigeonpea International Trial. In the previous season (1991/92) two sets of indeterminate short-duration pigeonpea lines consisting of 36 lines were evaluated; the first set at three locations (Ilonga, Nachingwea, and Ifakara) and the second set also at three locations (Ilonga, Naliendele, and Mlingano). In general the performance of the test lines in both sets was good and it was suggested that the trial be continued for one more season to confirm the superior performance observed in some of the lines.

Due to seed shortages in the 1992/93 season, however, the trial was limited to two locations for each set: Naliendele and Ifakara for the first set; and Ilonga and Ifakara for the second set. The trial at Naliendele failed because of excessive insect damage to pods, despite repeated spraying with Thiodan® 35EC. We have had good results from this site in previous seasons. At Ifakara, because of poor establishment, yields were generally low, and ranged from 0.18 to 0.75 t ha^{-1}. The highest-yielding lines were UPAS 120 (0.75 t ha^{-1}) and ICPL 89008 (0.73 t ha^{-1}).

In the second set the results were encouraging at Ifakara. The highest yielder, ICPL 86015, gave 1.78 t ha^{-1}, followed by ICPL 90053 (1.77 t ha^{-1}). Maturity duration ranged between 117 and 128 days at this site. The best results in this trial were obtained at Ilonga, with a location mean of 2.58 t ha-^{1}. The highest yields at Ilonga were recorded in ICPL 90043 (3.111 ha^{-1}) and ICPL 85045 (3.06 t ha^{-1}). The two sets of the trial need further evaluation.

Medium-duration pigeonpea trial. This trial consisted of medium-duration lines developed at IAC, and at Katumani, Kenya. In the 1991/92 season, 15 entries (including three new entries) were evaluated at eight locations. The trial was repeated in 1992/93 at seven locations to further compare new entries with the original lines.

The trial failed at Ilonga because of poor establishment caused by waterlogging (a result of heavy rains just after sowing). Results from the Hanang wheat complex have not been received. Table 1 shows the performance of the test lines in this trial at four locations. ICPL 332 was the highest yielder at Gairo and Ismani; it also yielded well at Hombolo. Over the season, yield levels of ICPL 332 have not been bad, but it has tended to perform well in good environments and very poorly in bad ones.

It is interesting to note that ICP 7035 W (a white-seeded version of ICP 7035) performed relatively well across locations. This line was tested for the first time in this trial. ICP 7035 W will replace ICP 7035 B, which was rejected in Babati because of its brown seed color.

Medium-duration Pigeonpea International Trial. This trial comprised new promising medium-duration lines from ICRISAT. Sixteen entries were evaluated for yield and other agronomic characters at two sites, Ilonga and Mlingano.

Table 1. Grain yields of medium-duration pigeonpea lines at four locations, Tanzania, 1992/93 cropping season.

Test line	Grain yield (t ha^{-1})				Overall mean
	Hombolo	Gairo	Ismani	Ifakara[1]	
ICPL 332	0.93	0.94	0.93	0.49	0.93
ICP 7035 W	1.06	0.90	0.74	0.47	0.90
ICP 8863	1.00	0.80	0.87	0.75	0.89
ICPL 84060	0.92	0.93	0.79	0.74	0.88
ICP 7035 B	0.84	0.94	0.77	0.84	0.85
Kat 60/8	0.94	0.81	0.75	0.64	0.83
Kat 50/3	0.84	0.77	0.88	0.42	0.83
ICPL 138	0.81	0.94	0.72	0.69	0.82
ICPL 270	0.99	0.74	0.82	0.92	0.82
ICPL 131	0.99	0.72	0.73	0.86	0.81
ICPL 87075	0.84	0.60	0.81	0.76	0.75
ICPL 87067	0.73	0.66	0.82	0.77	0.74
Local	0.61	0.57	0.66	0.27	0.61
ICPL 88027	0.76	0.31	0.54	0.11	0.54
ICPL 304	0.52	0.42	0.48	0.50	0.48
Location mean	0.85	0.74	0.75	0.62	
SE(±)	0.030	0.035	0.025	0.055	
CV(%)	23.2	27.6	23.8	56.8	

1. Ifakara was not included in the overall mean estimation because of the high CV.

At Ilonga the trial was affected by intermittent waterlogging because of heavy rains in Apr. ICPL 90104 gave the highest yield (1.68 t ha^{-1}), but this was not significantly higher than those of the controls. Days to maturity ranged from 170 to 175 (mean 172 days). At Mlingano ICPL 90094 gave the highest yield of 1.14 t ha^{-1}. Days to maturity ranged from 126 to 145 (mean 136 days). However, all the lines tested in this trial are small- and brown-seeded, both of which characters are unpopular with farmers.

Long-duration Pigeonpea International Trial. The landraces grown by farmers in Tanzania are of the long-duration type. These usually give very low yields, because of insect pests and the low yield potential of some of the landraces. The objective of this trial was to evaluate some of the newly developed long-duration pigeonpea lines for yield.

The trial consisted of 18 entries planted at two locations, Ilonga and Naliendele. The trial at Naliendele was abandoned because of poor performance. At Ilonga, heavy rains in April resulted in intermittent waterlogging and high variations in plant stand and yield. The highest yield (1.33 t ha^{-1}) was obtained from ICPL 87126. The lines matured in 199-204 days (mean 201 days). The trial will not be repeated, since these materials are very small-seeded, and small seed size is unpopular in Tanzania.

Preliminary nursery observation trial. This trial, consisting of 20 germplasm lines (4 extra short duration, 16 long-duration) from the Regional Pigeonpea Project, Malawi, was sown at Ilonga in one replication. The highest-yielding short-duration lines were ICPL 86012 (1.47 t ha^{-1}) and ICPL 146 (1.33 t ha^{-1}). The former had also shown yield superiority in previous varietal evaluations. In this group, maturity duration ranged from 85 to 88 days and 100-seed mass from 7 to 10.6 g.

In general the performance of the long-duration test entries was good. PGM 9208 (4.88 t ha^{-1}) and QP 37 (4.43 t ha^{-1}) gave the highest yields (Table 2). The 100-seed mass ranged from 13 to 17.4 g and maturity duration from 210 to 238 days. Most of the long-duration types were white-seeded. Large white seeds are popular, and these lines, therefore, hold a promise for acceptability to farmers. The long-duration lines will form a replicated trial in the 1993/94 season.

Table 2. Performance of entries in the pigeonpea preliminary nursery observation trial, Ilonga, 1993.

Pedigree/ Source	Days to		Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{-1})
	Flowering	Maturity			
Extra short duration					
ICPL 86012	59	88	115	9.5	1.47
ICPL 146	53	88	107	10.6	1.33
ICPL 87	53	85	84	7.0	1.27
ICPL 269	53	88	120	8.4	1.17
Long-duration					
PGM 9208	158	220	310	14.5	4.88
QP 37	133	215	278	14.9	4.43
PGM 9233	163	235	260	13.0	3.81
QP 14	141	210	316	15.0	3.59
QP 15	143	210	290	13.0	3.57
QP 38	143	210	290	15.1	3.44
PGM 9234	160	238	279	15.7	3.36
HY 3C	143	213	292	16.3	3.17
Royes	158	220	270	15.0	3.15
PGM 9226	151	220	290	14.4	3.04
ICPL 145	162	220	220	16.1	3.01
PGM 9201	163	235	300	13.9	2.51
PGM 9232	163	235	274	17.4	2.51
PGM 9215	141	215	273	15.5	2.29
PGM 9227	160	230	255	15.5	1.60
PGM 9229	160	230	260	15.9	1.04

We could not compare site means because the test lines were heterogenous (4 were extra short, while 16 were long-duration).

Seed Multiplication

Pigeonpea lines earmarked for on-farm testing were multiplied in the 1992/93 season. These include ICPL 87 W (22 kg) and ICPL 87 B (6 kg) in the short-duration group. ICPL 86005, although not increased this season, is also earmarked for on-farm testing. The medium-duration lines increased were Kat 50/3 (28 kg), Kat 60/8 (14 kg), ICPL 87067 (22 kg), and ICPL 87075 (64 kg). Some of the lines, e.g., ICPL 87 B, need further multiplication.

Breeding Research

A number of promising varieties have been identified in the varietal evaluations. These include:

- Short-duration varieties; ICPLs 151, 86005, 86012, 87 B, and 87 W,
- Medium-duration varieties; ICPL 87075, ICP 7035 B, ICP 7035 W, Kat 60/8, and Kat 50/3.

These varieties will be tested on-farm in the 1993/94 cropping season. However, the number of sites will be limited by the amount of seed available for some of the varieties.

Agronomy Research

Short-duration pigeonpea plant spacing. Research at IAC has shown that improved short-duration genotypes give high yields at close spacing (30 x 10 cm). 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 conducted at three locations to determine the extent to which interrow and within-row spacing could be increased without significant reduction of yield. A randomized complete block design with three replications was used. ICPL 86005 was sown at three levels of interrow spacing (40, 50, and 60 cm), two levels of within-row spacing (20 cm and 30 cm), and two levels of plants per hill (1 and 2). The trial was sown at Hombolo on 18 Jan, Gairo on 20 Jan, and Ilonga on 3 Mar 1993. Ilonga is classified as a wet environment, Gairo as moderately wet, and Hombolo as a dry environment. Results show that optimum spacing is probably different for each environment. There was no difference between close and wide spacing at Ilonga (wet), while at Hombolo (dry) high yields were obtained from closer interrow spacings (Table 3). It seems possible to increase spacing with no significant yield reduction in a wet environment. However, more work is needed before any concrete conclusions can be drawn.

Sorghum/pigeonpea intercropping. The short-duration pigeonpea lines introduced in Tanzania from ICRISAT have been tested and found to be very promising. As is

Table 3. Effect of plant spacing and number of plants per hill on grain yield of short-duration pigeonpea at Ilonga, Hombolo, and Gairo, 1993.

	1 plant $hill^{-1}$		2 plants $hill^{-1}$		
	Within-row spacing		Within-row spacing		
Interrow spacing (cm)	20 cm	30 cm	20 cm	30 cm	Mean
Ilonga					
40	2.64	2.48	2.67	2.61	2.60
50	2.13	2.52	2.69	2.61	2.49
60	2.47	2.18	2.36	2.20	2.30
Means (plants hill-')	2.40 (one)		2.52 (two)		
Means (within-row spacing)	2.49 (for 20 cm)			2.43 (for 30 cm)	
C V = 15%					
SE nonsignificant (P 0.05) for all effects					
Hombolo					
40	1.68	1.78	1.93	1.68	1.77
50	1.24	1.16	1.23	1.01	1.16
60	0.83	0.95	0.90	0.69	0.84
Means (plants $hill^{-1}$)	1.27 (one)		1.24 (two)		
Means (within-row spacing)	1.30 (for 20 cm)			1.21 (for 30 cm)	
SE for interrow spacing = ±0.059, all remaining effects nonsignificant (P 0.05).					
Gairo					
40	0.17	0.17	0.28	0.19	0.20
50	0.12	0.15	0.22	0.17	0.17
60	0.14	0.19	0.25	0.19	0.19
Mean (plants $hill^{-1}$)	0.16 (two)		0.22 (two)		
Mean (within-row spacing)	0.20 (for 20 cm)			0.18 (for 30cm)	
CV = 32%					
SE for plants $hill^{-1}$ = ±0.014, all remaining effects nonsignificant (P 0.05)					

presently done with other short-duration legumes, farmers may intercrop these short-duration pigeonpeas, once they are released, with other crops (e.g., sorghum). There is little available information regarding intercropping of sorghum with short-duration pigeonpea. An experiment was therefore conducted to determine the effect of such intercropping on overall productivity.

Sorghum (cv Tegemeo) and short-duration pigeonpea (ICPL 86005) were intercropped at various patterns at Ilonga and Hombolo, using a randomized complete block design with three replications. Sowing dates were 22 Jan for Hombolo and 4 Mar 1993 for Ilonga. A high level of competition between the intercrops was observed. Pigeonpea yields were *lower* when sorghum was sown at recommended densities than when sorghum was sown at customary (farmers') densities. However, land equivalent ratios were higher at the recommended density (Table 4). Surprisingly, pigeonpea yields were similar under wet (Ilonga) and dry (Hombolo) environments.

Short-duration pigeonpea—sowing date. It is thought that if the sowing of short-duration pigeonpea is delayed such that low temperatures prevail during a part of the

Table 4. Grain yields and land equivalent ratios (LER) from pigeonpea/sorghum intercrops at Ilonga and Hombolo, 1992/93.

Treatment	Pigeonpea grain yield (t ha^{-1}) Ilonga	Hombolo	Sorghum grain yield (t ha^{-1}) Ilonga	Hombolo	LER Ilonga	Hombolo
T1	-	-	2.01	1.13	1.0	1.0
T2	0.57	0.38	1.68	0.32	1.2	0.8
T3	1.45	0.57	1.42	0.76	1.4	0.6
T4	0.98	0.66	1.26	0.50	0.7	0.6
T5	1.38	0.88	1.60	0.86	0.5	0.3
T6	0.62	0.37	1.96	0.74	0.6	0.6
T7	0.89	0.75	1.40	0.23	1.1	0.6
T8	2.08	0.97	-	-	1.0	1.0
CV (%)	12.8	20.0	21.9	67.8	22.5	36.4
SE(±)	0.11	0.065	0.086	ns	0.07	ns

T1. Sole crop sorghum.
T2. Sorghum at recommended density (88 800 plants ha^{-1}) with 1 row of pigeonpea between sorghum rows.
T3. Sorghum at recommended density (88 800 plants ha^{-1}) with 2 rows of pigeonpea between sorghum rows.
T4. Sorghum rows paired 30 cm apart, 120 cm between pairs, 3 rows of pigeonpea between pairs (88 800 plants ha^{-1} of sorghum).
T5. Sorghum rows paired 30 cm apart, 150 cm between pairs, 4 rows of pigeonpea between pairs (88 800 plants ha^{-1} of sorghum).
T6. Sorghum at farmers' density (37 000 plants ha^{-1}) with 1 row of pigeonpea between sorghum rows.
T7. Sorghum at farmers' density (37 000 plants ha^{-1}) with 2 rows of pigeonpea between sorghum rows.
T8. Sole crop pigeonpea.

reproductive phase, the activity of some key pests might be reduced to below economic threshold levels. An experiment was therefore conducted to test this hypothesis under Tanzanian conditions.

ICPL 86005 was sown at three different dates at Ilonga (low altitude, wet environment, high mean temperature) and Gairo (medium altitude, intermediate mean temperature) under sprayed and nonsprayed conditions. A randomized complete block design with four replications was used with treatments arranged factorially. Sowing dates at Ilonga were 3 Mar, 19 Mar, and 5 Apr 1993; and at Gairo 18 Jan, 1 Feb, and 15 Feb 1993.

Results showed that yields at Ilonga could be increased by delaying sowing for 2 weeks during the main rains (Table 5). A part of this yield increase can be attributed to decreased pest incidence, as evidenced by lower damage scores in some cases. At Gairo, where insect pest pressure was lower, the spray regime had no significant effect on yield (Table 5). Pigeonpea yield at Gairo decreased with delayed planting, probably due to reduced moisture availability and low temperature rather than changes in insect pest incidence levels.

Maize/pigeonpea intercropping. Pigeonpea is intercropped with maize in the Babati area, a major production center. Farmers in the area use long-duration pigeonpea landraces, which often suffer from terminal drought stress. The available promising,

Table 5. Effect of sowing date and insecticide application on yield, yield components, and damage by pod-sucking bugs in short-duration pigeonpea at Ilonga and Gairo.1993.

	Ilonga			Gairo		
	Sprayed	Nonsprayed	Mean	Sprayed	Nonsprayed	Mean
Yield (t ha^{-1})						
1st sowing	2.31	0.11	1.21	0.29	0.21	0.25
2nd sowing	2.54	0.82	1.68	0.22	0.17	0.19
3rd sowing	0.91	0.24	0.57	0.16	0.13	0.15
Mean	1.92	0.39	0.22	0.17		
SE (±) for sowing	94.0			27.0		
SE (±) for spray	77.0			ns		
SE (±) for interaction	33.0			ns		
Pod damage (%)						
1st sowing	11.5	92.0	55.8			
2nd sowing	18.8	52.5	35.6			
3rd sowing	23.3	69.6	46.3			
Mean	20.5	71.3				
SE (±) for sowing	3.3					
SE (±) for spray	2.7					
SE (±) for interaction	4.7					
CV(%)				20.6		

improved medium-duration genotypes, which had been tested under sole crop conditions, were evaluated at Babati as a maize intercrop.

Two improved pigeonpea 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. A randomized complete block design was used with three replications, and treatments factorially arranged. The experiment was sown on 29 Jan 1993. Pigeonpea yields were similar under high and low densities, and also whether intercropped or sole-cropped. The local variety produced higher yield (1.60 t ha^{-1}) than the improved genotypes (Kat 60/8, 0.5 t ha^{-1} and ICPL 87075, 0.7 t ha^{-1}). Mean yields were 1.201 ha^{-1} for a sole crop and 0.90 t ha^{-1} under intercropping, confirming the existence of competition in intercropping.

Agronomy Research

The 3-year trial (1989-91) on the intercropping of short-duration pigeonpea with maize concluded this season. The recommendation made on the basis of trial results was that farmers in the low-altitude areas of Tanzania, who usually sow maize at a low density of 37 000 plants ha^{-1}, could intercrop maize with short-duration pigeonpea, using a ratio of 1:2 or 2:4 maize to pigeonpea rows.

Status of Pigeonpea Research in Malawi

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Introduction

Pigeonpea is widely grown in Malawi, especially south of Lake Malawi, in Salima (Lakeshore Plain) and Ngabu (Lower Shire Valley) Agricultural Development Divisions (ADDs). The crop is grown mainly by smallholder farmers as an intercrop with maize, sorghum, cassava, cotton, and many other crops. The bulk of the crop is for domestic consumption; small quantities are sold in local markets or processed and exported.

Thanks to the recent concerted efforts of the Ministry of Agriculture to develop the crop, there has been a general trend towards increased area and production since the 1988/89 season (Table 1). A number of factors have contributed to these increases, most importantly the introduction of the fusarium wilt resistant cultivar ICP 9145, and intensified extension campaigns. However, production levels remain low, and there is an urgent need to intensify research efforts to develop high-yielding genotypes resistant to fusarium wilt. There is also a need to expand pigeonpea production to Karonga, Mzuzu, Kasungu, and Lilongwe ADDs; suitable cultivars should be identified for these areas.

Table 1. Estimated area and production of pigeonpea in Malawi, 1988/89 to 1992/93.

Season	Area (ha)	Production (t)
1988/89	26 542	12 075
1989/90	37 437	18 256
1990/91	42 829	20 845
1991/92	44 293	10 267[1]
1992/93	70 598	35 392

1. The drastic reduction was due to drought.
Source: Ministry of Agriculture.

Current Production Systems under Smallholder Farms

All pulses in Malawi are grown either in pure stands or intercropped with staple food crops such as maize, sorghum, and cassava. However, the dominant system is inter-

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cropping. Often more than one type of pulse is interplanted in the same field with a staple crop, thus ensuring that smallholder farmers can harvest a variety of edible pulses to the extent possible under landholding and labor constraints.

Pigeonpea is grown rainfed, with only one crop per year. The crop is sown on ridges at the same time as the major component crop. Sometimes pigeonpea sowing is delayed until after the first weeding of the major crop. As a result, plant density is low, as are grain yields (0.2-0.5 t ha^{-1}). In a pure stand, pigeonpeas are planted on ridges spaced 90 cm apart, with 3 plants per planting station spaced at 90 cm (or sometimes less) within the row. Yields in pure stands are 1-2 t ha^{-1}.

Constraints to Pigeonpea Production

Several factors have contributed to low pigeonpea productivity in Malawi, the major constraints being:

- Limited landholdings;
- Lack of appropriate production technologies;
- Relatively low produce prices;
- Inadequate seed availability;
- Limited research on pigeonpea development.

Research Objectives

The overall objective of pigeonpea research has been to increase and stabilize grain yields by developing:

- Wilt-resistant cultivars with high yield potentials; and improved cultivars with acceptable grain quality and growth habit;
- Short-, medium-, and long-duration cultivars suitable for intercropping in small and/or large farms;
- Appropriate technologies for pigeonpea production under all farming systems;
- Reliable seed multiplication and distribution systems;
- Marketing and utilization channels involving agro-industries and other institutions.

Cultivar Development

In the 1980/81 season the Department of Agricultural Research (DAR) in collaboration with ICRISAT, made several collections of local landraces throughout the pigeonpea-growing areas of the country. The material was screened for adaptation, grain yield potential, and wilt resistance. Only three local cultivars (E-E-P62, 8020, and Mpherembe) had grain yields >2 t ha^{-1} under experimental conditions. However, all these were susceptible to wilt.

In the 1982/83 season, a sick plot was established at the Bvumbwe Research Station to screen all pigeonpea introductions against fusarium wilt. Since then we have been screening material introduced mainly from ICRISAT (Asia), Australia, and Kenya. Pigeonpea line ICP 9145 was identified from materials introduced from ICRISAT as resistant to wilt. This cultivar is late-maturing, resistant to fusarium wilt, and has acceptable grain qualities. It showed superior grain yields (>2 t ha^{-1}) in trials at Bvumbwe, Chitala, and Makoka Research Stations, and was released for production in the 1986/87 season.

Other materials which have shown promise are from Australia. These include the medium-duration (>150 days) genotypes QPs 14, 15, 37, and 38, Royes, and HY 3C. These have consistently yielded better than most local cultivars (Tables 2 and 3), but are susceptible to fusarium wilt. Limited seed multiplication of these cultivars is now under way pending their release.

On-farm evaluation. After 4 years of on-station testing, on-farm testing of the most promising lines began in 1992/93. The promising lines are ICPL 86012, ICPL 87105, QP 14, and QP 38; their release will depend on how they perform in the on-farm trials.

Pigeonpea Adaptability and Production Potential

The DAR, in collaboration with ICRISAT, has been conducting pigeonpea adaptation trials since 1986/87 at Makoka and Chitala Research Stations. The objective was to develop suitable technology for small to large-scale (semi-mechanized) commercial

Table 2. Grain yields in the Advanced Pigeonpea Variety Evaluation Trial at three locations in Malawi, 1991/92.

	Grain yield (t ha^{-1})			
Variety	Chitedze	Chitala	Baka	Mean
ICPL 9145	0.44	0.56	1.05	0.67
QP 14	2.03	0.74	2.23	1.66
QP 15	1.73	0.75	1.00	1.16
QP 37	1.75	0.70	2.00	1.48
QP 38	1.79	0.44	1.33	1.19
Royes	2.00	0.68	2.25	1.64
HY 3C	1.30	0.56	1.75	1.20
ICPL 86012	0.66	0.75	2.18	1.19
ICPL 87105	1.17	0.38	1.85	1.13
ICPL 87(C)	0.78	0.59	1.44	0.93
ICPL 151	0.39	0.89	2.25	1.18
ICPL 86005	0.32	0.54	2.05	0.98

Table 3. Grain yields of advanced pigeonpea lines at four locations in Malawi, 1990/91.

	Grain yield (t ha^{-1})				
Variety	Chitala	Makoka	Chitedze	Bolero	Mean
QP 14	0.47	1.67	1.22	0.32	0.92
QP 15	0.38	1.87	1.35	0.65	1.06
QP 37	0.43	2.10	1.31	0.53	1.09
QP38	0.35	1.77	0.95	0.47	0.89
Royes	0.41	2.55	1.32	0.60	1.22
HY 3C	0.27	1.67	0.83	0.31	0.77
ICPL 86012	0.29	1.39	2.25	0.36	1.07
ICPL 87105	0.45	1.69	2.84	0.86	1.46
ICPL 87(C)	0.32	1.02	2.27	0.52	1.03
ICPL 151(C)	0.45	1.87	2.74	0.76	1.46
ICPL 86005	-	-	1.72	0.59	1.16
ICP 9114 (control)	0.60	2.01	0.43	0.43	0.87

cultivation for both dry grain and green peas from short-duration pigeonpea cultivars, which can be rotated with tobacco, maize, etc. Among the extra short duration genotypes, ICPLs 83019, 86005, 86010, and 86012 have shown promise, with grain yields >2 t ha^{-1} in pure stand. Among the short-duration genotypes the following have shown grain yields >2 t ha^{-1}: ICPLs 87, 85049, 86005, and 86023.

Diseases and Insect Pests

Extensive screening of lines against fusarium wilt is done in Malawi. However, no research has been done on other diseases, or on insect pests of pigeonpea. During 1990/91 and 1991/92 an entomologist hired under the FAO/UNDP Pigeonpea Project conducted several surveys throughout the major pigeonpea-growing areas. The major insect pests were identified and documented. However, there is need for further surveys and to develop proper pest management methods.

Seed Multiplication

So far seed of the wilt-resistant variety ICP 9145 is being multiplied in all pigeonpea-producing ADDs. Breeder seed of ICP 9145 and other promising cultivars is being multiplied by the DAR.

Plant Protection Research on Pigeonpea in Malawi

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Introduction

Pigeonpea is one of the most important pulse crops in Malawi, particularly in the south, where it is consumed locally and also exported, either as whole grain or *dhal.* However, exports have been dwindling in recent years, partly due to disease problems, especially with fusarium wilt. Plant protection research conducted at the Bvumbwe Research Station and elsewhere in Malawi, is briefly described in this paper.

Fusarium Wilt

The pathogen *Fusarium udum* Butler causes wilt disease in pigeonpea and is prevalent in many countries. In Africa the disease occurs in Ghana, Kenya, Malawi, Mauritius, Tanzania, and Uganda (Nene et al. 1989). In Malawi it was first recorded in 1980, when it caused total crop loss in many districts of southern Malawi. A screening program was initiated at the Bvumbwe Research Station in the early 1980s involving local landraces, but all of them proved highly susceptible. ICRISAT pigeonpea lines, varieties, and germplasm materials were imported for further screening on a sick plot established at Bvumbwe. The plot is in addition naturally infested by *Meloidogyne javanica* and *M. incognita.* The station is 1183 m above sea level and experiences low temperatures.

ICP 9145, a Kenyan landrace, was identified as wilt-resistant at ICRISAT Asia Center (IAC) in 1979/80. After multilocational testing in India, Kenya, and Malawi (at Bvumbwe, where it showed nil wilt incidence for 2 seasons of testing), it was released in Malawi in 1987. This was the first wilt-resistant pigeonpea variety released in Africa. It is a long-duration variety with acceptable grain color and size, but takes slightly longer to cook than the local (wilt-susceptible) landraces. After its release, more materials were obtained from IAC. After at least 3 years of testing, eight wilt-resistant lines have been identified: ICPs 8859, 8863, 10958, 11292, 11299, 12733, and 12738, and ICPL 87119. These are now in their second season of trials at seven locations in Malawi.

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Root-knot Nematodes

ICRISAT had identified some pigeonpea lines resistant to *Meloidogyne* species. The lines were screened at Bvumbwe on fields naturally infested with mixed populations of *M. javanica* and *M. incognita.* The trial will continue for the next 2 seasons and susceptible lines will be discarded.

Disease Screening Trials

A multiple diseases screening trial was instituted at Bvumbwe. Essentially the trial involves the screening of many ICRISAT lines against fusarium wilt, sterility mosaic, and phytophthora blight. This is a continuous program and any line found resistant to these diseases will be tested in multilocational trials. A wilt screening trial was instituted in 1980, and is continuing. Multilocational trials are also in progress as described, to screen for resistance to fusarium wilt.

The work suffers from funding constraints, and it is very difficult for the research team to visit all sites.

Reference

Nene, Y., Sheila, V.K., and Sharma, S.B. 1989. A world list of chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* L. Millsp.) pathogens. Legumes Pathology Progress Report - 7. Patancheru, A.P. 502 324, India: Legumes Program, International Crops Research Institute for the Semi-Arid Tropics. 23 pp. (Limited distribution.)

Pigeonpea Breeding Research at the Kawanda Agricultural Research Institute, Uganda

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Introduction

Pigeonpea is an important grain legume in Uganda, being the most important food legume in northern Uganda and the second most important (after cowpea) in north-eastern Uganda. Even so, vast potential production areas, covering most parts of the country, are not sown to the crop. It is consumed mainly as a vegetable and as dry seed. Bottlenecks in pigeonpea production include, among others:

- Lack of improved short-duration varieties;
- A complex of insect pests;
- Storage pests;
- Nonavailability of inputs (e.g., farm labor, fertilizers, and insecticides);
- To a lesser extent, disease problems, especially fusarium wilt and *Mycovellociella cajani* (the perfect stage of cercospora leaf spot).

Production could, however, be increased by increasing farmers' awareness of market opportunities outside Uganda. This knowledge should be accompanied by a package to improve yield and quality parameters (consumer acceptability).

Recent Research

Following the Planning Workshop in Nairobi, Kenya in Mar 1992, the National Legume Programme in Uganda conducted a Rapid Rural Appraisal in the districts of Gulu, Apach, and Lira. Farmers indicated that high yield and earliness were the most important criteria for acceptability of new varieties. In response, 22 short-duration introductions were obtained from ICRISAT for further selections, and sown in Jul 1992 at the Kawanda Agricultural Research Institute (KARI). Grain yield and other characteristics of these introductions are shown in Table 1. Most of the lines flowered in 60-80 days. Yields ranged from 0.37 to 1.71 ha^{-1}; ICPLs 86005, 87091, 87101, and 87104 yielded over 1.5 t ha^{-1}. Seed sizes were small to medium, with 100-seed mass ranging from 7.6 to 12.6 g.

In Mar 1993 the same set of entries was sown with three replicates (three entries were replaced with more promising ones). The plot comprised three 6-m long

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Table 1. Characteristics of pigeonpea accessions tested on-station for two seasons at Kawanda Agricultural Research Institute, Kampala, 1992/93.

	Days to flowering		Plant height (cm)		100-seed mass (g)		Yield (t ha^{-1})	
Line	Jul 92[1]	Mar 93[2]	Jul 92	Mar 93	Jul 92	Mar 93	Jul 92	Mar 93
ICPL 87 B	60	70	54	50	9.9	9.3	1.05	1.07
ICPL 87 W	63	69	61	49	10.9	9.8	0.96	0.81
ICPL 151	60	70	60	42	10.9	9.9	0.70	0.28
ICPL 83016	70	69	80	65	11.6	10.3	1.12	1.05
ICPL 85012	-	69	-	35	-	10.7	-	0.35
ICPL 86005	63	66	58	48	11.3	10.4	1.70	1.19
ICPL 87091	71	76	76	68	11.1	12.9	1.64	1.46
ICPL 87101	60	69	61	51	11.5	10.1	1.64	0.91
ICPL 87102	66	62	65	51	10.9	10.1	1.43	1.08
ICPL 87104	59	67	56	46	10.2	10.3	1.57	0.87
ICPL 89026	59	-	48	-	9.7	-	0.58	-
ICPL 90028	-	62	-	48	-	11.5	-	1.50
ICPL 90001	79	56	53	65	10.3	10.5	0.95	0.60
ICPL 90007	63	59	44	47	8.0	8.7	0.40	0.57
ICPL 90008	63	62	45	45	7.6	10.7	0.52	0.31
ICPL 90009	64	69	62	69	7.9	9.4	0.90	1.02
ICPL 89029	-	68	-	50	-	11.2	-	0.84
ICPL 90031	69	69	54	56	9.5	9.3	0.37	0.71
ICPL 90033	80	69	55	62	9.0	9.5	0.44	0.50
ICPL 90034	74	69	49	69	11.0	9.1	1.09	0.69
ICPL 90036	80	69	57	56	9.3	9.0	0.76	0.50
ICPL 90040	72	69	55	74	9.5	8.8	0.71	0.31
Kat 60/8	88	89	75	82	12.1	12.6	1.00	0.71
K0 361	103	-	113	-	12.6	-	0.47	-
ICPL 87 (W KID 92LR)	73	-	50	-	9.3	-	0.70	-

1,2. Sowing dates.
1. Dimethoate insecticide applied twice; at flowering and 15 days later. 2. No insecticide.
- = not tested.

rows. Seven entries yielded more than 1 t ha^{-1} of grain (Table 1). Yields in this trial were lower than in the earlier trial; but even though the yields seem to be low, the pigeonpeas performed better than other legumes that were sown in KARI at the same time. The highest yielder was ICPL 90028 (a new entry), followed by ICPLs 87091, 86005, and 87102.

Varieties which were tested on-farm are Kat 60/8 and ICPLs 86005, 87091, and 87101. On-farm evaluation is being conducted in Arua, Gulu, and Apach districts with help from two nongovernmental organizations, CARE and World Vision. ICPL 87102 and ICPL 90028 were also ready to go on-farm. By Jul 1994 we will conduct a follow-up survey to assess impact.

Farmers are keen to get seed from us, so we need to have a good seed multiplication system, perhaps through nonformal means.

Survey of Pigeonpea Production and Postproduction Systems in Three Districts of Uganda

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Introduction

The area under pigeonpea in Uganda in 1991/92 was estimated at 78 000 ha, and production at 54 600 t (MAAIF 1992). Most of the crop is grown in the drier areas (Apach, Lira, Gulu, Kitgum, Soroti, and Kumi districts), where it is best adapted (Jameson 1970). Pigeonpea is grown mostly as an annual crop and is often intercropped with cereals, root crops, and other legumes. The average grain yields on subsistence farms are very low (< 1 t ha^{-1}) as compared with 2-4 t ha^{-1} obtainable from experimental plots (Musaana 1978). The main reasons for low yields on farmers' fields are thought to be the use of traditional unimproved landraces (6-10 months duration), damage by diseases and pests, and a narrow genetic base. Poor agronomic practices are followed and there are no sources of seed of improved varieties.

The Government of Uganda is now giving considerable emphasis to the diversification of export crops. It is expected that with improved production and marketing, pigeonpea may become an important new export crop. Improving production will, however, require the use of improved varieties with grain characteristics acceptable to farmers, and to the local and export markets. In turn, the efficient transfer of technologies to farmers requires an understanding of the circumstances under which they operate.

In order to get an overall perspective of the existing pigeonpea production systems, a survey was initiated in the major pigeonpea-growing areas of Uganda with the following major objectives:

- To document and characterize the general farming practices in these areas;
- To identify farmers' perceptions of the problems associated with their pigeonpea production systems;
- To identify levels and magnitudes of problems associated with pigeonpea production and postharvest systems;
- To provide baseline data for future follow-up monitoring and surveys;
- To obtain information necessary to design appropriate on-farm research trials.

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Survey Methodology

The survey target areas selected were all in northern Uganda, where pigeonpea production is highest. Three districts, Lira, Apach, and Gulu, were selected for the survey, and two counties (randomly selected) surveyed in each district. In Lira, the counties of Erute and Moroto; in Apach, Kole and Oyam counties; and in Gulu, Aswa and Omoro counties were selected. In each county three sub-counties were selected for the survey. The sampling unit was the household itself, and up to four households were selected randomly in each sub-county. The survey included a total of 37 sampling units (households).

A multidisciplinary team of scientists, consisting of two breeders, an agronomist, entomologist, and extension specialists participated in the survey conducted during Dec 1992. General background information was obtained from the District Agricultural Office in each district. Thereafter, farmers were visited randomly along the travel routes. A pre-set questionnaire was used to probe farmers' perceptions; and observations were made on pigeonpea farms to record other relevant information (pests, production practices, and varietal characteristics). Samples of field pests were collected for identification. Seed samples were collected for storage loss assessment, storage pest identification, and as a germplasm collection for characterization.

Varietal and Seed Character Preferences

In the three districts surveyed, farmers were asked to rank food crops by priority (in terms of area and production). Pigeonpea sole crop ranked near the bottom (out of 16), but the millet/pigeonpea intercrop ranked second highest, after sweet potato (Table 1). All households surveyed had grown some pigeonpea, and the household mean area for pigeonpea was 0.5 ha per family. Medium-duration varieties were the most common (Table 2). The long-duration variety Adyang was grown in Gulu, and Adong in Lira district. In Apach and Lira districts, the medium-duration Apio Elina is the predominant variety. It gives moderate yields, cooks easily, and has medium-sized seeds with mixed white (cream) and brown seed colors. The variety Agali, which is grown in Apach and Lira districts, had most of the above characteristics but is reported as being difficult to cook. Adyang is the predominant variety in Gulu; its major characteristics are long duration, high yield, short cooking time (unless stored for very long), medium-sized seeds, and good storability. The variety Agogi grown in some parts of Lira district, has the same characteristics. Farmers, it appears, perceive that short cooking time is an important attribute in a cultivar, in addition to high yield. Long-duration varieties could be accepted provided they are high-yielding and cook quickly.

The major sources of seed were reported to be farmers' own carryover stock (100%), neighbours and, on rare occasions, market purchases. Most households had never previously tried new pigeonpea varieties, largely due to their unavailability. In places where new varieties were tried, as in Apach, they were derived from the immediate surroundings. Farmers are, however, willing to grow new varieties if seed is provided.

Table 1. Priority of food crops cultivated in Gulu, Lira, and Apach districts, Uganda, as ranked by farmers, 1992.

Crop	Priority[1] in				Rank
	Apach	Gulu	Lira	Mean	
Millet	11	9	13	11	10
Sorghum	8	4	6	6	7
Maize	6	7	8	7	8
Sesame	2	8	5	5	5
Groundnut	5	3	7	5	5
Beans	1	9	3	4	4
Pigeonpea	11	15	13	13	14
Soybean	10	15	10	12	11
Cassava	7	1	4	4	3
Sweet potato	4	2	2	3	1
Millet/pigeonpea intercrop	3	6	1	3	2
Beans/sorghum intercrop	11	15	11	12	13
Banana	11	9	9	9	9
Groundnut/maize intercrop	16	12	16	14	15
Cowpea	16	13	16	15	15
Others	9	13	13	11	11

1. 1 = highest priority, 16 = lowest priority

Table 2. Percentage of farmers growing the major pigeonpea landraces in three districts of Uganda, 1992.

Local variety/Duration	District		
	Apach	Gulu	Lira
Apio Elina (Apio)/Medium	70	0	67
Agali/Medium	30	0	25
Adyang (Agogi)/Long	0	89	41
Adong/Long	0	0	41

The most sought after characteristics were found to be, in order of priority, high yield, short duration, short cooking time, good storability, white or cream seed color, large to medium seed size, and taste.

Production Practices

Yields of pigeonpea were generally regarded as low and estimated at only 0.36 t ha^{-1} in the mixed pigeonpea/millet intercrop (the most common). Farmers attributed this low yield to lack of good seed and heavy pest damage. Most of the harvested crop is both sold and kept for home consumption (63%); only 37% of farmers grew the crop exclusively for sale.

Most farmers (53%) indicated that they grew pigeonpea in all soil types; there was no soil type preference for pigeonpea production. Land preparation was usually (69%) found to be different and more intense than that for other crops. It involved the preparation of a fine seed bed, probably because pigeonpea is sown together with millet. All varieties are sown at the same time, irrespective of maturity duration, with 67% sown in Mar and 19% in early Apr. The seeds are mostly broadcast, with only a small proportion row-planted. Sowing is done only once a year and in exceptional cases (3%), twice.

In the millet intercrop, where medium- and long-duration types are grown, seed rate was variously estimated at 12 kg ha^{-1} in Lira and Apach and 2.5 kg ha^{-1} in Gulu. The most common intercrop with pigeonpea in all the districts was millet; other intercrops were groundnut and cassava (mostly in Gulu) (Table 3). The commonest reason given for choosing a particular intercrop was crop compatibility. Sole crops, if encouraged, could reduce the need for fine seedbed preparation.

Table 3. Percentage of intercropping with pigeonpea, for major crops in three districts of Uganda, 1992.

Crop	Apach (%)	Gulu (%)	Lira (%)
Millet	100	100	100
Groundnut	10	89	8
Sesame	0	0	0
Cassava	0	44	0
Sorghum	0	0	0
Other	0	11	33

Crop rotation involving pigeonpea/millet and other crops is practised by all farmers. The commonest sequence was sesame, sorghum, cassava, or cotton followed by a pigeonpea/millet intercrop, and thereafter a range of crops including sorghum, beans, or maize. Land is often left fallow after the first or second crop after the pigeonpea/millet intercrop. Various reasons were given for crop rotation, including enhanced soil fertility, need for a fine seedbed, reduced pest damage, weed control, etc.

Field Pests

According to farmers, the most serious pests were pod borers (*Helicoverpa armigera*), a range of pod-sucking bugs (*Clavigralla* spp), and flower beetles (*Pachnoda sinuata*). Other pests include leaf-eating caterpillars, termites, and thrips (*Megalurothrips* spp). Levels of damage were reported as medium for the pod borers, pod-sucking bugs, and blister beetles, and slight for the other pests.

Field observations during the survey revealed that the most serious field pests were the pod-sucking bugs, mainly *C. gibbosa.* This was most serious in Lira and Apach districts, where in some instances the whole crop was destroyed. Pest population levels at all stages of development were very high. Damage by *H. armigera* was apparent in all the districts, but losses due to this pest were considered lower than those caused by *C. gibbosa.* Populations of flower thrips (*Megalurothrips* spp) were also very high in all three districts but damage and loss levels were uncertain. Flower beetle populations were generally low, but some damage to flowers was observed. It is important to note that the survey was conducted when the harvest of medium-duration plants was either complete or in progress, and as such pest attack and magnitude of damage could not be properly assessed.

Harvesting and Storage Methods

Harvesting methods ranged from breaking the whole plant (in Lira and Apach) to picking mature pods (in Gulu). The harvested crop is dried and threshed (in Lira and Apach) or directly stored in pods after drying (in Gulu). In Apach, clean seeds are stored. In Gulu, pods are stored mostly in outdoor granaries. Where seed storage is practised, methods used include a sealed traditional store (*tua)* and other small indoor containers. There is a need to conduct further investigations to determine the most effective and practical storage methods.

The storage duration for pigeonpea was indicated as being 9-12 months. However, farmers were concerned about the stored produce. The major concern was damage by bruchids (100%); others were theft (26%) and rats (6%). The extent of bruchid damage was stated as slight for storage duration <3 months and severe for storage duration >6 months. Chemicals for the control of storage pests were not available in most of the surveyed areas, and attempts to control bruchids included the use of ash admixture (80%), red pepper (chillies) admixture (61%), sunning (49%), pod storage in granaries (26%), and chemicals (17%). In addition to the above methods, other methods that farmers were aware of (but did not use) included slight boiling and roasting. Pest damage during storage can be reduced by developing appropriate storage and processing methods.

Storage Pests

During the survey, seed samples were collected from households or markets, losses assessed, and pigeonpea storage pests identified. The only storage pest found in pigeonpea on-farm was the bruchid (*Callosobruchus chinensis*). Damage to seed by bruchids was calculated at 4.5% for a mean storage period of only 2.8 months in Lira and Apach. In Gulu, such an estimate was not possible as the long-duration crop was still in the field. After incubation for 1 month, again only *C. chinensis* were found in the grain samples. Damage levels had, however, dramatically increased to 55.2%. Samples collected from the markets contained *C. chinensis* and had damage levels of less than 1% for a storage duration of 1-2 months. After incubation for 1 month, the damage level went up to only about 5%. Most of the pigeonpea in the market is normally sorted, and weevils and damaged seeds are discarded. This partly explains the low level of bruchid damage.

Marketing

Most of the farmers (51%) marketed less than 25% of their pigeonpea harvest, 27% marketed 26-50%, and 22% of the farmers never sold any. Nearly 59% sold the pigeonpea in village markets only and 41% in both village and town markets. Marketing of pigeonpea was more or less continuous soon after harvest. The bulk of it was, however, sold immediately after harvest (82%), mostly due to the need for immediate cash. Selling at 3 months or less after harvest (54%) was predominantly due to fear of pest damage (57%) and need for immediate cash (26%); sales made 3-6 months after harvest (56%) were mostly due to better prices (48%) and fear of insect damage (40%), while selling at 7-9 months (44%) was mostly due to the very good prices obtained then (68%) and fear of extreme damage by insect pests (21%). Selling just before the next harvest (13%) was also due to the good prices obtainable (66%). Other reasons given were, need for storage space for the next crop (18%) and fear of pest damage (16%).

Apart from the supply and demand factor, prices were also adversely affected by bruchid damage, especially at mid- and late selling times. The extent of bruchid damage was found to determine final selling prices (Table 4). Damage of less than 2% had no effect on price. Damage of 43-47% caused a price reduction of 50% or more and often the crop was no longer marketable. At 48-52% damage the crop was most

Table 4. Effect of bruchid damage on selling price of pigeonpea, as reported by farmers in three districts of Uganda, 1992.

Bruchid damage (%)	Reduction in selling price (%)
<2	Nil
3-7	10(22%)[1]
8-12	10(40%)
13-17	10-20
18-22	10-30
23-27	20-30
28-32	30-40
33-37	30-50
38-42	40- >50

1. Figures in parentheses show percentage of respondents providing the respective estimate.

often not marketable and if sold, the price reduction was more than 50%. Grain with more than 52% damage was not marketable at all. The unmarketable pigeonpea was used as animal feed (48%), split and cooked for food (29%), thrown away (17%), and on rare occasions sold in village markets (6%).

Just before the next harvest, however, most families (70%) will have run out of pigeonpea. In such instances, to meet family needs, pigeonpea is then bought from markets (23%), bartered with other crops (18%), borrowed from friends (9%), or other legume substitutes used (9%). When available, almost all farmers harvest green pigeonpea just before the main (grain) harvest.

References

Jameson, J.J. 1970. Agriculture in Uganda, 2nd edn. UK: Oxford University Press.

MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). 1992. Production estimates for major crops in Uganda. Uganda: MAAIF.

Musaana, M.S. 1978. A study of the hereditability and environmental influence of major agronomic and yield characteristics in pigeonpeas. MSc Thesis, Makerere University, Kampala, Uganda.

Pigeonpea Storage Pests in Uganda, and Sun-drying for Disinfestation

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Introduction

In stored grain legumes, the most serious pests reported in Asia are *Callosobruchus maculatus, C. chinensis, C. analis,* and *C. theobromae.* In Africa they are *C. maculatus* (Le Pelley 1959, Southgate 1978, Mphuru 1978), *C. chinensis,* and *C. artrolineatus* (Bridwell 1918). In Uganda both C. *maculatus* and *C. chinensis* have been observed in stored pigeonpea (Davies 1960).

Figures given for storage losses in legumes are generally unreliable (Harris and Lindblad 1978). In pigeonpea they are also scarce; estimated loss in India is 5%, and figures are unavailable for other pigeonpea-producing countries. Information on field infestation is equally scanty. Apart from Bridwell's (1918) observations on field infestation of pigeonpea by *C. chinensis* in Hawaii, no other definite information on patterns of infestation is available. Field infestation and damage levels, though generally low, nevertheless have serious implications because bruchids multiply very rapidly within a short time once transferred (with seeds) into storage systems, causing very high damage levels. Caswell (1968) observed that field infestation of only 1.1% in seeds at harvest resulted in 50% damage after only a few months of storage. In Uganda, during 6 months storage, 21% weight loss has been reported in some legumes (Silim et al. 1990).

This paper summarizes the studies reported in three separate communications: Pigeonpea storage pest distribution, infestation, and damage; Field infestation of pigeonpea by *C. chinensis;* and Sun-drying for disinfestation against pigeonpea storage pests. The objectives of these studies were to:

- Identify storage pests of pigeonpea;
- Estimate losses at various postproduction stages;
- Determine the importance of field infestation by bruchids;
- Develop a simple solar disinfestation device to control *C. chinensis* infestation.

Storage Pest Distribution, Infestation, and Damage

A total of one hundred and ten 500-g samples of dry pigeonpea grain were collected: 30 samples from farmers, 30 from nine village markets, and 50 from five town markets in the districts of Apach, Gulu, and Lira, the major pigeonpea-growing

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districts in Uganda. Additional samples were collected from city markets in Kampala. Where possible, harvest dates and origin of the crop were recorded. Insects were sieved out, identified, and counted. The grain was then incubated for 45 days and again all insects sieved out, identified, and counted. The bulk of the samples were collected 2 months after harvest. It could not be determined whether or not the samples contained an admixture of old pigeonpea.

Major Pests

The major pest in samples collected from farms was *C. chinensis.* The fact that infestation was seen as quickly as 2 months after harvest indicates that *C. chinensis* infestation occurs in the field and is carried over to storage. At the village market level *C. chinensis* was the predominant species in all three districts (mean of 99.5%). There was very low infestation (0.5%) by *C. maculatus.* Infestation by *C. maculatus* (which is a common pest of cowpea) could be because cowpea and pigeonpea are marketed side by side.

In town markets *C. chinensis* was again the predominant species (mean 96.9%); infestation by *C. maculatus* was low (mean 2.8%). Significantly, *Acanthoscelides obtectus,* a common pest of stored beans, was also found (mean 0.3%). This too could be a result of cross-infestation. In city markets at Nakawa and Owiino (the major outlets in Kampala), *C. chinensis* was again the predominant species (mean 87.7%). Populations of *C. maculatus* (mean 9.7%), and *A. obtectus* (2.5%) were markedly higher than in the samples from farmers and village/town markets. These again indicate cross infestation; cowpea and beans are traded more heavily in city markets.

Damage Levels

Infestation in samples obtained from farmers 2 months after harvest was 3.5%, mainly due to field infestation. Damage levels were significantly lower in Gulu district (where pigeonpea is mainly stored as whole pods) than in Apach and Lira districts, where seed storage is common.

In village markets mean damage level was only 1.9%, probably because farmers discard damaged grain before sale. In town markets, mean damage level was 3.9%. This increase may be due to inability to sort the large bulk handled and/or contamination from old stock. In city markets, where larger bulks are handled and there is a high probability of contamination, damage levels were 7.1%.

After 45 days of storage in the laboratory, damage levels (mean for all districts) increased to 42.8% for farmers' samples, 48.5% for village market samples, 42.6% for town market samples, and 47.8% for city market samples. District-wise damage levels were 23.4% in Gulu, 49.7% in Apach, and 55.34% in Lira.

Pod Development and Infestation

A seed sample of a local variety Apio Elina was collected from Lira district in Aug 1991, and the crop grown from this seed lot in Kawanda (sown in Mar 1992) was used to study the relationship between pod development and infestation. Eight different pod development stages were sampled: pod just forming (Ra), early pod fill (Rb), late pod fill (Rc), mature green pod (Rd), mature yellow pod (Re), mature dry pod, early (Rf), mature dry pod, late (Rg), and dry grain (shelled) (Rs).

Moisture and dry matter contents at each stage were determined using the oven drying method (Table 1). Twenty pods at each stage were sampled. In addition, 20 randomly selected pods from each stage were caged while on the plant. Two pairs of 24-h old *C. chinensis* adults were introduced into each cage and allowed to lay eggs for 3 days. Thereafter the insects were gently removed from the pods (but remained caged to avoid field infestation). These pods were picked at maturity, dried for 4 days, and shelled. Seeds were then incubated separately from each pod in glass vials until emergence, and the number of emerging adults recorded.

Table 1. Moisture and dry matter contents and mean incubation periods of *Callosobruchus chinensis* in different pod stages of pigeonpea, Kawanda Agricultural Research Institute, Uganda, 1992.

Pod stage[1]	Moisture[2] (%)	Dry matter[2] (%)	Incubation period[2] (days)
Ra	84.9	15.2	45.1 c
Rb	76.3	22.7	44.7 c
Rc	73.3	27.7	45.1 bc
Rd	69.1	30.9	32.2 b
Re	59.4	40.6	42.0 b
Rf	30.1	69.9	No emergence
Rg	18.6	81.4	No emergence
Rs (seed)	15.1	84.9	38.3 b

1. See text for explanation.
2. Mean of 20 pods *for* each stage.
Means followed by the same letter are not significantly different ($P<0.05$).

Infestation occurred at all stages of pod development with the exception of Rf and Rg stages. There was significant variation between stages in mean incubation period (Table 1). Adult emergence patterns also differed: Rd had double emergence peaks, as did Rc and Re (but to a lesser extent). Polymorphism, as evidenced by the presence of two morphs under field conditions, probably improves survival of *C. chinensis,* by ensuring that some eggs will develop, and adults disperse, over a range of dry matter contents and moisture levels.

It also appears that at very low moisture and very high dry matter content, *C. chinensis* is not capable of infesting pigeonpea through the pod (Table 1). After shelling, however, seeds are very rapidly infested.

Pod Characteristics and G *chinensis* Infestation

Six different kinds of pods were investigated in the laboratory immediately after harvest: pods with stipes attached/detached; pods with field damage specifically by *Helicoverpa armigera* and damage through dehiscence; hairy and non-hairy pods. Forty pods in each category were placed in individual glass vials, and four pairs of 24-h old *C. chinensis* introduced into each vial. These were allowed to incubate for 60 days, and adult emergence was noted.

Pods harvested with or without stipes (pedicels) were equally infested, and showed no differences in points of adult emergence. This indicates that although non-stiped pods get damaged, the damage is not so severe as to expose seed sufficiently to allow direct infestation of the seed, nor does it allow emergence (through cracks) from within the pod.

Both *H. armigera* damage and dehiscence (splitting of pods) greatly increased infestation levels in the field and in storage. In both cases oviposition preference was significantly higher on the seed than on the pod. Apparently the holes and splits on pods attracted and permitted the entry of *C. chinensis* into the pod to lay eggs on the seeds.

Infestation was significantly affected by pod hairiness and by the choice/no choice option. Though eggs were laid on both types of pods (fewer on hairy pods than nonhairy ones), no adult emergence was recorded from hairy pods. Emergence from non-hairy pods was both internal and external, but significantly larger numbers emerged externally than internally. This indicates that though *C. chinensis* is capable of infesting pods, very few (>1%) are capable of successful penetration of the pods. And of those that succeeded in penetrating the pod only 33% managed to emerge from the pod to infest other pods. This in effect means that long self-elimination of *C. chinensis* is possible if pigeonpea is stored in the pod.

Sun-drying for Disinfestation of Grain

Chemicals are the most effective way to control pests, but are unavailable or too expensive for many smallholders; in addition, there is a danger of abuse due to lack of knowledge about proper usage (Silim et al. 1991). As an alternative to chemical control, farmers adopt various methods to prevent losses. These include the use of neem oil (Sangappa 1977), treatment with vegetable oils (Girish et al. 1974), the use of airtight containers (Srivastava et al. 1991), and solar disinfestation (Silim et al. 1991). In this study we designed and tested a simple solar disinfestation device against C. *chinensis.*

The device consisted of a black (solar radiation absorbing) polythene sheet (90 x 90 cm) as an underlayer, placed directly on an insulating mattress made from threshed pigeonpea pods (1 x 1 m). The mattress was covered with a soil layer 2-4 cm thick. Infested pigeonpea was then spread in a uniform layer (0.75 cm thick) on the black polythene sheet and covered with a sheet of transparent polythene. To maintain internal temperature and limit heat escape, the edges of the sheets were folded over.

Apart from black polythene, three other underlayer materials were tested: blue cotton cloth, brown sisal sack, and white polythene sack.

One hundred grams of previously disinfested pigeonpea grain was divided into 50-g lots, placed in glass jars, and separately infested with 20 pairs of 24-h old adults of *C. chinensis.* The samples were divided into two subsamples which were infested 10 days apart and later mixed, to ensure the presence of different development stages of the pest at the time of solar treatment. Each subsample was standardized to 250 eggs 3 days after infestation (before larval penetration of the seed), by scraping off the excess eggs. All adults were then removed. This 100 g of infested grain was thoroughly mixed with 1.9 kg of disinfested grain to make up 2 kg, which was solarized for 6 h.

Solar heating treatments were replicated 4 times in a paired design. For each treatment, percentage germination was determined from 100 seeds soon after treatment. After solarization, samples were incubated in the laboratory and observed for emergence, and percentage mortality calculated.

Adult emergence data was subjected to analysis of variance. The temperature attained in each treatment was measured every 30 min for 6 h. The trial was conducted on a clear, sunny day in Feb 1993 at the Kawanda Agricultural Research Institute, Uganda.

Results of Solarization

The mean temperature in solar heating treatments reached 80.9°C, while ambient air temperature was 24.9°C. Under ambient conditions a mean of 397 adults emerged from the seed, with mortality of 9.7%. In contrast, there was 100% mortality in solar-heating treatments, with no adults emerging. Percentage mortality of adults and seed viability for different treatments are given in Table 2.

These results indicate that except for the white polythene sack, all the materials used as underlayers in the disinfestation device were effective in controlling

Table 2. Effects of solarization treatments on mortality of *Callosobruchus chinensis* and percentage germination of treated pigeonpea grain, Kawanda Agricultural Research Institute, Uganda, 1993.

Treatment	Mean number of adults emerging	Adult mortality (%)	Seed viability (%)
Black polythene	0.0 c	100	72.6
Blue cotton cloth	0.0 c	100	80.3 b
Brown sisal sack	0.7 c	99.8	90.0 ab
White polythene sack	10.3 b	89.9	90.0 ab
Control[1]	90.3 a	9.7	97.0 a

1. Ambient conditions, with no overlayer or underlayer.

Means in a column followed by the same letter are not significantly different ($P < 0.05$).

C. chinensis infestation in pigeonpea. Even though percentage germination was significantly reduced in the black polythene and blue cotton cloth treatments, this was largely compensated by the high pest mortality. The experiment will be repeated on somewhat cloudy days and with shorter treatment times to determine the loss in germination,

Ntoukam (1989) and Murdock and Shade (1991) used a similar solar 'dryer' to disinfect cowpea against *C. maculatus.* Murdock and Shade (1991) also reported that high temperatures were similarly effective against the pest, without affecting germination or cooking time in cowpea.

References

Bridwell, J.C. 1918. Notes on Bruchidae and their parasites in the Hawaiian Islands. Hawaii Entomological Society Proceedings 3(5):465-505.

Caswell, G.H. 1968. The storage of cowpea in northern Nigeria. Samaru, Zaria, Nigeria: Institute for Agricultural Research.

Davies, J.C. 1960. Coleoptera associated with stored products in Uganda. Eastern Africa Agricultural Journal 20 (3):199-201.

Girish, G., Singh, K., and Krishnamurthy, K. 1974. Studies on the oviposition and development of *Callosobruchus maculatus* (F.) on various stored pulses. Bulletin of Grain Technology 12:113-116.

Harris, K.L. and Lindblad. 1978. Loss caused by insects, mites and micro-organisms. Postharvest grain loss assessment methods. USA: American Association of Cereal Chemists. 193 pp.

Le Pelley, R.H. 1959. Agricultural insect pests of East Africa. Nairobi, Kenya: East African High Commission. 307 pp.

Mphuru, A.N. 1978. Occurrence, host plants and relative importance of *Callosobruchus* species in Tanzania. Report of Survey, Tanzania. 9 pp.

Murdock, L.L., and Shade, R.E. 1991. Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpea by solar heating. Annual Review of Entomology 37:228-231.

Ntoukam, G. 1989. Exploring the feasibility of using solar radiation to control Bruchids (*C. maculatus*). Cameroon Biosciences Society. 21 pp.

Sangappa, H.K. 1977. Effectiveness of oils as surface protectants against the bruchid *Callosobruchus chinensis* infestation on red gram. Mysore Journal of Agricultural Science 11:391-397.

Silim, M.N., Odogola, W., and Amenent, J. 1990. A technical report of the post-harvest project in Uganda. Rome, Italy: Food and Agriculture Organization of the United Nations, and Kampala, Uganda: Ministry of Agriculture. 130 pp.

Silim, M.N., Odogola, W., and Amenent, J. 1991. Pages 39-40 *in* Technical report of the postharvest loss prevention project (PEL/uga/001), 1987-91. Rome, Italy: Food and Agriculture Organization of the United Nations, and Kampala, Uganda: Ministry of Agriculture.

Southgate, S. 1978. New junior synonyms of *Callosobruchus analis* (F.) and *Callosobruchus dolichos* (Gyll) (Coleoptera: Bruchidae) with notes on distribution. Journal of Stored Produce Research 4:61-63.

Srivastava, S., Mishra, D.P., and Khare, B. 1991. Effect of insect infestation on biochemical composition of pigeonpea (*Cajanus cajan* L.) seeds stored in mud bin. Bulletin of Grain Technology 26:120-125.

Current Status of Pigeonpea Research in Zambia

J. Mulila-Mitti[1]

Introduction

During the period 1982-88 the then Grain Legumes Research Team in Zambia (now known as the Food Legumes Research Team) conducted significant research on pigeonpea. The genotypes evaluated were restricted to medium-duration introductions and long-duration local landraces. Some agronomy work, including intercropping studies, was also conducted. Two lines, ICP 7035 and 423/50/3, were found promising and are in the pre-release stage. These lines, however, were not adequately tested on-farm. From 1988 to 1991 pigeonpea research was suspended due to limited resources.

In the 1992/93 season, pigeonpea evaluation trials were resumed, with funding from the United Nations Development Programme (UNDP) for a 5-year period. With closer collaboration with ICRISAT (including the posting of an ICRISAT pigeonpea breeder at the Chitedze Research Station in Malawi), more diverse pigeonpea genotypes developed at ICRISAT were made available for testing in the 1992/93 season.

Pigeonpea and Government Agricultural Policy

The new government agricultural policy is to promote crop diversification in order to improve both national and household food security. There is also an emphasis on generating sustainable technologies. One aspect of achieving sustainable food production is ensuring long-term soil fertility. Pigeonpea fits well with the policy because it contributes to food security and soil fertility improvement. The extra short and short-duration genotypes should provide food during the 'hunger period' (late Feb to mid Mar), when most crops are still not ready for harvest. Medium- and long-duration pigeonpeas are potential components of agroforestry systems, which are receiving a lot of research attention in the country.

On-station Evaluation Trials, 1992/93

Four international trials (on extra-short-, short-, medium-, and long-duration pigeonpea) were conducted at the Msekera Research Station, Chipata, in the 1992/93

1. Mt. Makulu Research Station, Private Bag 7, Chilanga, Zambia.

season. All trials were sown in a randomized complete block design with four replications. The trials were sown with the first rains in mid Nov. However, crop stands were uneven as a long dry spell followed the sowing.

At the time of reporting, data were available only for the extra short and short-duration trials. Harvesting of the medium- and long-duration trials had not been completed.

The extra short duration trial had 20 entries. The mean yield for the trial was 0.84 t ha^{-1} with the highest-yielding entry, ICPL 88034, producing 1.61 t ha^{-1} (Table 1). Mean plant height was 71 cm (range 55-136 cm). The number of days to maturity ranged from 97 to 122, with a mean of 103 days.

Table 1. Performance of entries in the Extra Short Duration Pigeonpea International Trial (Determinate), Msekera Research Station, Zambia, 1992/93.

Line	Days to 50% flowering	Days to maturity	Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 88034	68	122	136	10	1.61
ICPL 88001	64	106	71	12	1.40
ICPL 88009	68	113	103	10	1.38
ICPL 84023	63	104	74	8	1.30
ICPL 90001	66	103	88	13	1.16
ICPL 90011	65	106	74	12	1.03
ICPL 89027	58	100	61	11	1.02
ICPL 90008	60	102	61	10	0.95
ICPL 4	64	99	67	6	0.85
ICPL 88007	59	99	62	10	0.80
ICPL 90012	62	104	77	10	0.71
ICPL 88015	62	103	61	11	0.70
ICPL 88003	59	100	58	10	0.66
ICPL 90005	58	99	59	10	0.63
ICPL 83015	63	100	65	8	0.58
ICPL 85010	61	100	58	9	0.58
ICPL 87095	57	99	57	9	0.50
ICPL 90004	62	103	69	11	0.35
ICPL 89020	57	97	57	10	0.29
ICPL 89024	58	98	55	8	0.23
Mean	62	103	71	10	0.84
SE(±)	0.8	2.9	3.70	0.05	0.174
CV (%)	2.23	4.9	8.9	9.1	37.2

In the short-duration trial, 18 entries were tested. The mean yield was 1.66 t ha^{-1}; the highest-yielding entry, ICPL 88034, gave 3.5 t ha^{-1} and only one entry yielded below 1 t ha^{-1}. Mean plant height was 143 cm (range 89-169 cm); days to maturity ranged from 115 to 135, with a mean of 127 days (Table 2).

Table 2. Performance of entries in the Short-duration Pigeonpea International Trial (Indeterminate), Msekera Research Station, Chipata, Zambia, 1992/93.

Entry	Days to 50% flowering	Days to maturity	Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 88034	71	130	169	11	3.50
ICPL 88715	69	129	157	11	2.82
ICPL 90044	70	129	148	11	2.21
ICPL 89018	89	128	158	11	2.19
ICPL 85045	72	133	167	13	1.94
ICPL 86015	69	130	158	11	1.89
ICPL 90046	67	128	150	12	1.67
ICPL 90050	70	129	133	11	1.63
UPAS 120	68	125	143	10	1.52
ICPL 90048	66	125	131	12	1.48
ICPL 86023	69	123	111	14	1.45
ICPL 89007	70	135	156	14	1.31
ICPL 90045	66	125	124	11	1.17
ICPL 87114	67	121	130	11	1.18
ICPL 90054	72	132	178	14	1.12
ICPL 90053	67	127	145	11	1.06
ICPL 90043	68	130	126	11	1.05
ICPL 90052	66	115	89	10	0.71
Mean	69	127	143	11.6	1.66
SE(±)	0.08	1.1	5.7	0.04	0.309
CV (%)	1.9	1.4	6.9	5.3	32.2

The results for the two trials were impressive. In the 1993/94 season the materials will be tested further on more diverse environments to get conclusive data.

On-farm Varietal Trial, 1992/93

This trial was conducted in order to assess the suitability of four promising medium-duration pigeonpea varieties in smallholder farms in selected areas of Eastern Province. The four varieties, ICP 7035, 423/50/3, NPP 670, and HY 3C, were evaluated at six sites (two sites each in Kamlaza, Feni, and Chanje areas). The trials were sown between 11 and 21 Dec in a randomized complete block design with three replications. They were harvested by end May/early Jun 1993, 165-173 days after sowing.

Results are reported from three trials. The remaining three trials were written off for various reasons. Seed quality, and consequently plant stand, were poor for HY 3C and NPP 670. Beetles and bugs caused severe damage at all locations, resulting in a very high coefficient of variation (57%), and rendering the results unreliable. The trial will be repeated in the 1993/94 season.

Collaborative Research

Apart from the pigeonpea research work conducted by the Food Legumes Research Team, other programs utilize pigeonpea in their work. Collaborative research involves ICRISAT, NARS in the region, and the International Center for Research in Agroforestry (ICRAF).

The agroforestry research team based at Msekera has been testing medium- and long-duration genotypes in alley-cropping and improved fallow experiments; the Soil Conservation and Agroforestry Extension Program has been introducing pigeonpea as a means of preventing soil erosion; and the Nthaka Yatha Project on the restoration of degraded soils in Eastern Province plans to include pigeonpea in their trials. In addition, most farming systems research programs across the country are using pigeonpea in their soil fertility improvement trials.

Pigeon pea Research for Rainfed and Irrigated Production Systems in Western and Central Sudan

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Introduction

Pigeonpea is traditionally grown in northern and central Sudan as a minor crop. It is grown along irrigation channels in Gezira (central Sudan) or to demarcate small farmholdings in northern Sudan along the Nile. It is sometimes used as a living fence on dairy farms. The crop has potential in the semi-arid areas of western Sudan; in the irrigated areas of central and northern Sudan in rotation with other crops (in addition to being a border crop); and in rotation with semi-mechanized sorghum systems in eastern Sudan. Area and production estimates are not available.

The crop is locally known as *Lubia addassy,* and is consumed as boiled dry grain, particularly during the month of fasting (Ramadan). The foliage is also used as feed for livestock, and the dry stems as firewood. Its diversified consumption as dehulled grain (as a substitute for lentil in *dhal*) is growing, and the increased demand has benefited the country's dehulling agro-industry. Because of its multiple uses, and its role in the enhancement of soil fertility and in the sustainability of rainfed sorghum and millet production systems, pigeonpea is attracting increased attention from policy makers.

This paper reports the results of investigations in the rainfed millet-based cropping system in western Sudan and the irrigated system in the Gezira area.

North and South Kordofan (Rainfed)

Kordofan state, which covers 24% of the country, is the main target area for pigeon-pea initiatives in western Sudan. Annual rainfall in Kordofan ranges from 150 to 800 mm, increasing from north to south. The soil types range from sandy in the north to heavy cracking clays in the south. The 1992 rainy season was above normal.

Varietal Trial and Observation Nursery, 1992/93

Nine varieties obtained from ICRISAT and continuously grown since 1987 at El-Obeid (western Sudan), were again evaluated with a local control. A randomized block

1. El-Obeid Research Station, P.O. Box 429, El-Obeid, Sudan.
2. Gezira Research Station, P.O. Box 127, Wad Medani, Sudan.

design was used with four replications. Plot size was 7 rows of 7 m length, with 75 x 25 cm spacing. Three to four seeds were sown per hole, and later thinned to one plant. The soil was chisel-harrowed after a shower in late Jun.

The trial was sown on 7 Jul and harvested on 7 Dec 1992. The results (means) were as follows: 90 days to 50% flowering; plant height 91 cm; grain yield 0.18 t ha^{-1}; yield of dry stems 0.70 t ha^{-1}. Varieties did not vary in yield: ICPL 312 produced the highest yield of 0.25 t ha^{-1} as compared to 0.20 t ha^{-1} for the local landrace.

Three varieties—ICPL 87102 (short-duration), Kat 60/8 (medium-duration), and Kat 878 (long-duration)—received from ICRISAT's Eastern Africa Regional Cereals and Legumes Program (EARCAL) in Kenya were sown in a nonreplicated observation nursery on 31 Jul 1992. Spacing was 50 x 20 cm for all varieties. Dry pods were harvested thrice: 18 Dec 1992, 14 Jan and 15 Feb 1993.

The short-duration variety reached a height of 56 cm, and produced 0.19 t ha^{-1} of dry grain and 0.42 t ha^{-1} of dry biomass. The medium-duration type produced lower grain yield and biomass than the short-duration type; the long-duration type grew to a height of 140 cm, and produced 0.17 t ha^{-1} of dry grain and 4.35 t ha^{-1} of dry biomass. Both medium- and long-duration pigeonpeas remained green until they were grazed in March.

Intercropping Trials of Pigeonpea with Sesame and Groundnut

In the 1992/93 season, six intercrop combinations of pigeonpea with sesame and groundnut were tested at El-Obeid, using different row ratios of pigeonpea: sesame or groundnut, and different ratios of pigeonpea: sesame/groundnut within a row. Sole crops were also tested. The varieties used were Hirehiree for sesame, Sodiri for groundnut, and the local landrace for pigeonpea. Spacings were 60 x 20 cm for groundnut and sesame, and 60 x 40 cm for pigeonpea. The trials were sown on 15 Jul and harvested on 5 Dec 1992. The coefficients of variation in the experiments were very high, hence valid conclusions cannot be drawn.

Pigeonpea Performance in Different Intercropping Systems

Pigeonpea performance was compared in the 1992/93 season in different intercropping systems at El-Obeid and Dabkar in North Kordofan and El-Quake and Angarko in South Kordofan. Pigeonpea represented the minor crop, and one of millet/sorghum, groundnut, sesame, or cowpea was the major crop. Millet was sown in North Kordofan, but was replaced by sorghum in the clay soils of South Kordofan.

The treatments were arranged in a randomized block design with four replications. Twelve rows of each intercrop (3:1 ratio of majonminor crop rows) and six rows of each sole crop were grown, all of 5 m length. Interrow spacing was 60 cm, while within-row spacings were 40 cm for sorghum and pigeonpea, 50 cm for millet, 30 cm for cowpea, and 20 cm for sesame and groundnut. The varieties used were Gadam El-Hamam for sorghum, Hirehiree for millet, Hirehiree or Zirra 9 for sesame, Sodiri for

Table 1. Pigeonpea intercropping trials with several crops, North and South Kordofan, Sudan, 1992.

	Grain yield of main crop ($t\ ha^{-1}$)				Grain yield of pigeonpea ($t\ ha^{-1}$)			
Treatment	El-Obeid	Angar-ko	El-Quake	Dab-kar	El-Obeid	Angar-ko	El-Quake	Dab-kar
Millet/pigeonpea	0.56	-	-	-	0.02	-	-	0.16
Sorghum/ pigeonpea	-	0.45	0.25	-	-	0.05	0.008	-
Groundnut/ pigeonpea	0.66	0.10	0.76	0.19	0.03	0.08	0.008	0.06
Sesame/pigeonpea	0.24	1.17	0.24	0.31	0.07	0.06	0.008	0.39
Cowpea/ pigeonpea	0.57	0.21	0.27	0.16	0.04	0.07	0.009	0.16
Sole pigeonpea	-	-	-	-	0.20	0.14	0.190	1.00
Sole millet	0.86	-	-	0.60				
Sole sorghum	-	0.74	0.62	-				
Sole groundnut	1.11	0.13	1.64	0.84				
Sole sesame	0.28	0.39	0.54	0.43				
Sole cowpea	0.72	0.43	0.77	0.52				

groundnut; Ain El-Gazal for cowpea, and a local pigeonpea. Two seeds were sown per hole and later thinned to one plant. The seeds were treated with Aldrex-T® @ 3-5 g kg^{-1}. Sowing was done on 15 Jul at El-Obeid, 27 Jul at Angarko and Dabkar, and 6 Aug at El-Quake. Harvesting was between 6 and 12 Dec 1992 at all sites.

The results are summarized in Table 1. Pigeonpea yields were very low, mainly due to heavy infestation by blister beetles (*Mylabris* spp). It would first be necessary to manage the crop effectively before fitting it into different cropping systems.

Pigeonpea in Rotation with Millet and Sesame

Pigeonpea variety ICPL 87 was grown at El-Obeid after millet and sesame (a 2-year rotation), the main crops of the area. The trial was conducted in a randomized block design with three replications. The grain and dry biomass yields of pigeonpea were not significantly different with different preceding crops. The mean grain yield was 0.33 t ha^{-1} and dry biomass yield 1.60 t ha^{-1}.

Long-term experiments need to be conducted to quantify the effect of pigeonpea (in rotation) on soil organic matter and yields of millet and sesame.

Pigeonpea-*Acacia Senegal* Agroforestry System

Acacia Senegal is a major component of the traditional bush-fallow cultivation system in western Sudan. Pigeonpea is not grown in the region but farmers know it because grain (mainly from central Sudan) is sold in the local markets.

In this experiment, conducted at El-Obeid in the 1992/93 season, seeds/seedlings of the local pigeonpea variety were sown/transplanted between rows of 6-year old

Table 2. Performance of pigeonpea varieties under irrigation at Wad Medani, Gezira, Sudan, 1992.

	Days to		Plant height (cm)	Yield (t ha^{-1})	
	Flowering	Maturity		Grain	Stalk
Short-duration					
ICPL 151	76	139	64	0.88	0.49
Kat 50/3	91	175	120	1.04	1.72
Kat 60/8	91	166	102	0.58	0.82
ICPL 87 W	76	136	50	0.75	0.84
ICPL 84023	75	153	50	0.60	0.26
ICPL 88027	76	177		1.24	0.61
ICPL 87104	82	150	51	0.62	0.84
ICPL 88026	76	208	52	0.93	0.51
ICPL 87 B	76	172	62	0.94	0.39
Medium- and long-duration					
Kat 66	106	187	136	0.33	1.21
ICPL 88035	96	144	102	1.16	0.94
ICP 11917	104	164	89	0.60	0.55
ICP 9105	94	164	132	1.54	1.81
Kat 2	108	206	138	0.31	1.25
ICP 8959	92	157	127	1.05	0.94
ICP 3869	85	141	110	1.49	1.09
ICP 8006	105	165	110	0.65	0.61
ICP 12734	102	167	106	0.77	0.58
ICP 9103	105	167	109	1.44	1.08
Kat 109	116	175	94	0.56	0.65
WB 20 (El-Obeid)	91	168	131	1.08	0.79
ICPL 312 (El-Obeid)	111	174	116	0.75	0.52
Local variety	121	176	129	0.96	0.96

A. senegal Two, three, or four rows of pigeonpea (seeded and transplanted) were used in a 2 x 3 factorial design arranged in complete blocks with three replications. *Acacia* was grown at 5 x 5 m and pigeonpea at 1 x 1 m. There was no apparent effect on survival or growth (height and shoot thickness) of *Acacia* due to interplanting of pigeonpea. The transplanted pigeonpea had a mean yield of 0.04 t ha^{-1}, whereas seeded pigeonpea had 0.01 t ha^{-1}. The number of rows did not influence pigeonpea yield. Again, the yields of pigeonpea were very low; perhaps other intercrops may be more productive.

Central Sudan (Gezira), Irrigated System, 1992/93

Nine short-duration and 14 medium- and long-duration varieties including a landrace as a local control, were sown on 20 Aug 1992 on approximately 250 m^2 area each, on ridges 60 cm apart. Within-row spacing was 15 cm for short-duration varieties and 30 cm for the others (the latter were sown on alternate ridges). Five irrigations were applied, spread throughout the season. The observations are summarized in Table 2.

The yields were not attractive considering that five irrigations were given. The constraints need to be analyzed to provide information on how to obtain economic yields.

Comparison of Grain and Dehulling Characters of Pigeonpea Samples from Sudan and Kenya

Sitt el Naffar M. Badi[1]

Introduction

Twenty kilograms of large-seeded pigeonpea were received from ICRISAT/EARCAL (Eastern Africa Regional Cereals and Legumes Program) in Kenya. The purpose was to run a trial to determine whether large-seeded varieties have better decortication qualities and consumer acceptability than the Sudanese medium-seeded varieties.

Materials and Methods

The varieties were evaluated physically and chemically. Dehulling properties, cooking time, and taste were also evaluated. All analytical tests were run according to AACC (American Association of Cereal Chemists) or IACC (International Association of Cereal Chemists) specifications. The dehulling test was done on TADD (Tangential Abrasive Dehulling Device) and UMS (United Milling System) laboratory dehullers, for both conditioned and nonconditioned seeds. In the latter case, seeds were tempered by adding water to maintain moisture content at 10% for 16 h. The taste panel used the Hedonic scale, and cooking was done using a fiber determination apparatus.

Results

Results are shown in Table 1. The Kenyan seeds were larger, denser, and lighter in color, and had higher protein and ash contents, than the Sudanese seeds.

Conditioned seeds (both Sudanese and Kenyan) gave higher extraction rates than nonconditioned seeds (Table 2). The Kenyan variety generally gave higher extraction rates than the Sudanese variety (Table 2).

The cooking test was carried out on both dry and presoaked (immersed in water for 16 h) seeds. Soaking reduced cooking time, especially in the Sudanese variety: from 80 (unsoaked) to 40 min (soaked), and from 70 (unsoaked) to 40 min (soaked) for the Kenyan seed. The unsoaked Sudanese variety had a distinct flavor and

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bitter aftertaste, perhaps because of its high tannin content. Both samples, when cooked after soaking, had a loose seed coat (more on the Kenyan sample) and cracks on the seed surface. The results suggest that soaking may be a cheap and effective way to reduce cooking time and thus cut down on the usage of expensive fuel wood. More experiments are planned to determine 'optimal' soaking time.

Table 1. Physicochemical analysis of red (Sudanese) and white (Kenyan) pigeonpea seed, Food Research Center, Sudan, 1992.

Cultivar	Density ($g\ L^{-1}$)	100-seed mass (g)	Moisture content (%)	Ash content[1] (%)	Protein content[1] (%)	Fat content[1] (%)
Red pigeonpea (Sudan)	847.0	10	6.5	4.32	20.75	1.00
White pigeonpea (Kenya)	854.8	14	6.5	4.75	21.53	1.08

1. Calculated on dry basis.

Table 2. Dehulling properties of Sudanese and Kenyan pigeonpea using different dehulling methods, Food Research Center, Sudan, 1992.

Sample	Dehuller used	Moisture content (%)	Dehulling time (min)	Extraction rate (%)
Nonconditioned seed				
Sudanese	TADD/UMS[1]	6.5/6.5	2.3/2.3	76.5/75.5
Kenyan	TADD/UMS	6.5/6.5	2.3/2.3	80.2/81.7
Conditioned seed				
Sudanese	TADD/UMS	10.0/10.0	2.3/2.3	78.9/79.2
Kenyan	TADD/UMS	10.0/10.0	2.3/2.3	82.8/87.8

1. TADD = Tangential abrasive dehulling device, UMS = United milling system.

Pigeonpea in Namibia

D.J.M. Marais[1]

Pigeonpea is not grown in Namibia, and most farmers in the country are unaware of the crop. The objectives of pigeonpea research in Namibia are to:

- Test the suitability of pigeonpea as a cash or food crop;
- Evaluate cultivars for adaptability to Namibian conditions;
- Introduce adaptable cultivars to farmers in on-farm trials.

Research in 1992/93

One trial involving short- and medium-duration pigeonpea cultivars was sown at two locations, Omahanene and Bagani. The rains started very late, and as a result the trial was sown late, at the end of Jan 1993. Harvesting was in progress in end Sep.

The crop seems to be well adapted in Namibia, but insect pests are a major constraint. Namibia has a very dry climate; we hope that further research will lead to the development of suitable drought-tolerant cultivars.

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Pigeonpea Breeding Research in Mozambique

M. Libombo, J. Arias-Fondion, and A. Paulino[1]

Introduction

In Mozambique, pigeonpea is normally intercropped or mixed-cropped with such other crops as cassava and sorghum, or grown as hedgerows. Farmers usually sow pigeonpea in Dec-Jan; harvesting starts in July and continues until August. The harvest thus falls during the middle of the dry season, when farmers have no other legume crops in their fields.

The crop is grown in different parts of the country, mainly in the north. Total production is not known (although the crop is important), but average yields are 0.35-0.50 t ha^{-1} (Heemskerk 1985). Pigeonpea is normally cultivated by subsistence farmers, using long- and medium-duration cultivars with minimal inputs, on small areas of about 0.5 ha per family. The harvest is usually sufficient for their own consumption.

Major Constraints

The major constraints to the production of pigeonpea (and other legume crops in Mozambique) are lack of seed, poor crop management, low yield potentials, fusarium wilt, nematodes, and pod borers. All these contribute to low yields.

Currently, farmers grow mainly long-duration varieties with large cream or brown seeds. Our breeding program is oriented basically towards providing farmers with suitable varieties through applied research. The specific objectives are:

- To evaluate a new collection of 180 lines obtained from ICRISAT Asia Center (IAC);
- To evaluate the yield and photoperiod response of promising lines under natural environmental conditions.

Research in 1992/93

Twenty local germplasm lines and 180 introduced varieties from IAC were sown in 1992 at the Ricatla Research Station, near Maputo, under rainfed conditions and on

1. Instituto Nacional de Investigacao Agronomica (INIA), Caixa Postal 3658, Mavalene, Maputo, Mozambique.

very poor sandy soils. The initial results were encouraging, and the study is being continued. Preliminary results indicated that the medium- and long-duration varieties performed better than the short-duration ones.

Future Research Plans

Pigeonpea is an important food source, particularly since it matures at a time when there is no other grain legume in farmers' fields. It is therefore our priority to pursue selection and breeding work, and promote the most suitable varieties. Future research plans are:

- To collect as many representative samples as possible of cultivars grown in the main production areas;
- To evaluate, purify, characterize, and maintain these local materials;
- To start a varietal screening program;
- To use the results of these efforts as a basis for further varietal improvement.

Reference

Heemskerk, W. 1985. Especiese variedades de feijoes existentes em Mocambique. Maputo.Mocambique:Instituto Nacional de Investigacao Agronomica. 35 pp.

Pigeonpea in Zimbabwe

Rosalia Dube[1]

Introduction

Pigeonpea is relatively unknown in the farming systems of Zimbabwe, and as a result, has not so far received any substantial research attention from the national program. However, the crop is gradually becoming important, especially along the eastern borders of Zimbabwe. Pigeonpea is a multipurpose crop, and is likely to play a major role in nutrition (for both rural and urban poor) and provide fuel and fodder, especially in the dry season. Being a leguminous plant, it will also help to improve soil fertility.

Pigeonpea is an important component of the diet of people of Asian origin. Since this population (and consequently demand for pigeonpea) is large the government might include the crop in its research projects. This will eventually lead to reduced imports and saving of scarce foreign currency. Many crops such as soybeans and potatoes are not indigenous. However, because of their wide acceptance by both commercial and small-scale farmers, they have received greater research attention than any of the indigenous crops. As with any other crop, most farmers have no objection to growing pigeonpea as long as it has well-defined uses at both commercial and subsistence levels and yields are high enough to compete with already existing crops for land and other resources.

Current Research

The Southern African Development Community (SADC)/International Centre for Research in Agroforestry (ICRAF) Agroforestry Project currently based at the Department of Research and Specialist Services, is doing some work on pigeonpea. Their current major thrust is to incorporate multipurpose trees, especially legumes, as a means of recycling nutrients. Pigeonpea in agroforestry will improve soil fertility, and complement other food crops, rather than compete with them for limited land and resources.

1. Department of Research and Specialist Services, P.O. Box 8108, Causeway, Harare, Zimbabwe.

Country Workplans

Kenya—Collaborative Research Workplan

The collaborative research workplan for Kenya covers three main areas:

- On-farm evaluation of short-duration pigeonpea;
- Seed multiplication;
- Back-up research (multilocational varietal trials, screening for disease resistance).

On-farm Evaluation of Short-duration Pigeonpea

Justification and Objectives

Several short-duration cultivars have been developed in Kenya and at ICRISAT Asia Center. These cultivars mature within 120-160 days compared to the long-duration types that take from 180 to over 300 days in the field. In on-station trials, short-duration cultivars have been successfully sown during both the short and long rains and/or ratooned to give a second crop within 1 year. They also give stable yields in drier areas where the long-duration cultivars usually fail to even flower. However, most of the short-duration cultivars have not left the station; those which have are not widely grown by farmers. Therefore, there is a need to popularize these cultivars with the farmers. The study aims to:

- Evaluate some of the improved pigeonpea cultivars in farmers' fields;
- Assess farmers' reactions to the newly improved technologies.

Methodology

Genotypes. Four genotypes out of Kat 60/8 and ICPLs 87091, 87109, 90028, and 87 W. Kat 60/8 and ICPLs 87091, 87109, and 90028 will be tested at all locations except the coast. The coast will have ICPLs 87091, 87109, 90028, and 87 W.

Locations. Locations were selected according to agroecological zones as follows:

Agroecological zone	District	Location
LM 4	Makueni	Emali (5 sites)
UM 4	Machakos	Kimutwa (5 sites)
UM 5	Makueni	Kampi ya Mawe (5 sites)
CL 2-4	Kwale	4 sites
CL 4	Kilifi	4 sites (near Kilifi and Mtwapa)
CL 4	Kilifi	2 sites (near Mtwapa)
CL 4	Mombasa	4 sites (for vegetable types)

Design. Plot size 10 x 10 m, replicated twice. Spacing 10 x 40 cm for ICPLs 87 W, 87091, 87109, and 90028; 30 x 60 cm for Kat 60/8. Cropping systems:, monocrop. Sowing dates: short and long rains 1993/94. The trials will be managed by farmers, under the supervision of scientists.

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

Expected Outputs

Intermediate

- Performance of the short-duration cultivars in different agroecological zones under farmer management will be documented;
- Farmers' preferences for variety, seed size, plant height, and maturity duration will be determined;
- Socioeconomic factors relating to the improved cultivars will be evaluated.

Long-term

- It is expected that the research will popularize and promote the spread of these cultivars in the region.

Budget

	ICRISAT funding[1] (US$)
Travel	1 000
Accommodation and per diem	600
Supplies	
Chemicals, fertilizers, etc.	550
Records	100
Communication	50
Support to extension, etc.	300
Total	2 600

1. Details of funding by the national program will be provided later.

Seed Multiplication

Justification and Objectives

In order to promote the spread of improved pigeonpea cultivars, large quantities of quality seed are required for trials within the country and throughout the region; for on-farm testing and demonstrations by extension staff; and most important, for those farmers who frequently visit the stations and make requests for improved seeds. Bulking of promising cultivars is therefore necessary. The purpose of this exercise is to increase seed of promising pigeonpea cultivars for experimental purposes, on-farm testing, demonstrations, and future release.

Methodology

Bulking of pre-release cultivars. Cultivars: Kat 60/8, NPP 670, Kat 777, Kioko, and Kat 81/3/3. Location: Katumani. Plot size 0.5 ha per cultivar.

Seed increment for elite lines. Twenty cultivars. Location: Katumani. Plot size 10 m x 10 rows.

Management. Land preparation, sowing, weeding, guarding, selfing, spraying, and harvesting.

Expected Outputs

- 500-1000 kg of each of the prerelease lines;
- 50-100 kg of each of the elite lines;
- Increased area under improved cultivars.

Budget

	ICRISAT funding[1] (US$)
Travel	150
Operations	
Land preparation	100
Labor	500
Supplies	250
Total	1 000

1. Details of funding by the national program will be provided later.

Back-up Research

This involves two studies: multilocational varietal trials and screening for resistance to fusarium wilt and cercospora leaf spot.

Multilocational Varietal Trials

Justification and Objectives

Elite lines are continuously being generated by hybridization and germplasm introductions. Preliminary evaluation of some of these lines at the National Dryland Farming Research Centre (NDFRC), Katumani and by the University of Nairobi have shown that they have remarkable potential in the regions where pigeonpea crops are grown. It is therefore important to clearly identify the areas of adaptation for these elite lines.

The trial aims at testing the performance of newly developed lines of different maturity groups in different agroecological zones to determine their adaptation.

Methodology

Genotypes. Forty-five genotypes (15 each of extra short, short-, and medium- to long-duration), plus controls for each maturity group.

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

Design. Randomized block design with 4 replications. Plot size 5 m x 5 rows. Spacing 10 x 30 cm for extra short, 10 x 40 cm for short-, and 10 x 50 cm for medium- to long-duration lines.

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

Expected Outputs

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

Budget

	ICRISAT funding[1] (US$)
Travel	
Transport	250
Per diem	100
Operational costs	
Labor	500
Supplies (chemicals)	300
Supplies (bags)	100
Office	50
Total	1 300

1. Details of funding by the national program will be provided later.

Screening for Resistance to Fusarium Wilt and Cercospora Leaf Spot

Justification and Objectives

Surveys have shown that fusarium wilt and cercospora leaf spot are the major pigeonpea diseases in Kenya. Wilt causes yield losses of 10-20% every year; losses of up to 80% due to cercospora have been reported in bad years. The development of resistant varieties is therefore vital to Kenyan agriculture. The study aims at screening breeding lines for resistance to wilt and cercospora leaf spot.

Methodology

Genotypes. Germplasm, breeding lines.

Location. Katumani (wilt sick plot).

Design. Plot size: 3 m x 1 row. Two replications.

Data. Wilt and cercospora damage scores; yield.

Expected Output

- Identification of lines tolerant to wilt and cercospora leaf spot.

Staffing

NARS	ICRISAT
P.A. Omanga - Breeder	S.N. Silim - Agronomist
G. Kamau - Agronomist	Laxman Singh - Breeder
P.M. Kimani - Breeder	S. Tuwafe - Breeder
B.M. Wafula - Agronomist	S.B. King - Pathologist
W. Songa - Pathologist	ICRISAT entomologist
Extension staff	ICRISAT socioeconomist

Kenya Workplan Budget Summary

	ICRISAT funding[1] (US$)
On-farm evaluation	2 600
Seed multiplication	1 000
Back-up research	
Multinational trials	1 300
Screening for resistance to diseases	1 000
Total	5 900

1. Details of funding by the national program will be provided later.

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

Most of the research on pigeonpea in Tanzania has been conducted on research stations; the promising lines identified have not been tested on farmers' fields. The pigeonpea project has identified short-duration lines (among others) which need to be tested on-farm with the following objectives:

- To evaluate on-farm performance;
- To elicit farmers' perceptions of the varieties being tested;
- To determine the potential and subsequently monitor adoption of the new varieties.

Methodology

Locations. Ten sites (five each in Kilosa and Tanga).

Genotypes. Eight varieties. Short-duration: ICPLs 151, 86005, 86012, and 87 W. Medium-duration: ICPL 87067, ICPL 87075, Kat 60/8, and ICP 7035 W.

Design. Randomized block design with 2 replications. Spacings: 45 x 10 cm for short-duration and 60 x 20 cm for medium-duration lines.

Expected Outputs

- Farmers made aware of the new varieties;
- Recommendations on variety release(s); possible releases of suitable varieties.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	1000	660
Operations		
Field inputs	300	200
Labor	200	200
Laboratory supplies	150	100
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 is lack of seed. The aim of this work is to 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 and diseases. Plot sizes will be 0.2-0.5 ha for each variety.

Budget

The budget for seed multiplication is US$ 1800, of which $ 1000 will be provided by the Tanzanian national program and $ 800 by ICRISAT.

Back-up Research

Back-up research involves varietal trials for long-, medium-, and short-duration pigeonpea; agronomy studies (on sowing date, spacing, and cropping systems); and screening for wilt tolerance.

Long-duration Pigeonpea Varietal Trial

Justification and Objectives

Long-duration pigeonpea landraces give low yields (300-500 kg ha^{-1}) on farmers' fields. Reports suggest that the low yields are due to, among other factors, insect pest attack and lack of high-yielding varieties. This study aims to:

- Determine whether newly developed (introduced) and local landraces have high yield potentials;
- Select lines with high yield and grain characteristics acceptable to farmers, for eventual release.

Methodology

Genotypes. Twenty long-duration lines.

Locations. Five locations: Ilonga, Ifakara, Babati, Mlingano, and Naliendele.

Design. Randomized complete block design with 3 replications. Four rows of each variety in a 12 m^2 plot; 20 plots. Spacing 75 x 40 cm.

Expected Outputs

- On-farm testing of superior lines;
- Identification and characterization of superior performers, and recommendations for their release.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	200	130
Operations		
Field inputs	150	100
Labor	720	380
Laboratory supplies	80	60
Office supplies	100	60
Communication	150	-
Reports and publications	150	70
Total	1 550	800

Medium-duration Pigeonpea Varietal Trial

Justification and Objectives

Most pigeonpea cultivars currently grown by farmers are long-duration and to a lesser extent medium-duration landraces. Medium-duration cultivars are potentially advantageous because they are exposed to terminal drought stress for a shorter period than long-duration cultivars. ICRISAT has developed several superior medium-duration lines. We intend to test these superior lines to determine their performance under Tanzanian conditions.

Methodology

Genotypes. Eighteen entries.

Locations. Four locations: Ilonga, Mlingano, Ismani, and Machingwea.

Design. Randomized complete block design, plot size 12 m^2, four rows per plot. Spacing 75 x 40 cm.

Expected Outputs

- On-farm testing of selected lines;
- Recommendations for the release of superior performers.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel (in-country)	200	130
Operations		
Field inputs	150	100
Labor	720	450
Laboratory supplies	80	50
Office supplies	60	40
Communications	30	20
Reports and publications	120	10
Total	1 360	800

Short-duration Pigeonpea Varietal Trial

Justification and Objectives

Long-duration varieties commonly grown in Tanzania take up to 8 months to mature, and as a consequence suffer from terminal drought stress. Pest levels are often high, and insecticide application is difficult because the crop often reaches a height of 2 m. ICRISAT has developed short-duration varieties that mature in 4 months and are less than 1.5 m tall. These short-duration varieties complete their growth within a more favorable moisture regime and are easy to spray. Our tests indicate that these varieties have high yield potentials. The trial aims to evaluate the performance of these lines under Tanzanian condition, and subsequently to test superior lines on-farm.

Methodology

Genotypes. Thirty-six entries, comprising 18 each of determinate and non-determinate types.

Locations. Four locations: Ilonga, Mlingano, Ismani, and Nachingwea.

Design. Randomized complete block design with 4 replications, plot size 4.8 m^2, 4 rows per plot. Spacing 30 x 10 cm.

Budget

	Funding (US$) by	
	NARS	1CRISAT
Travel	160	100
Operations		
Field inputs	120	100
Labor	576	300
Laboratory supplies	64	20
Office supplies	48	20
Communications	24	10
Reports and publications	96	50
Total	1 088	600

Short-duration Pigeonpea: Effect of Sowing Date on Yield and Pest Damage

Justification and Objectives

Results in eastern and southern Africa indicate that short-duration pigeonpeas experience heavier pest damage than long-duration cultivars. This is probably because the reproductive phase of short-duration cultivars occurs at a time when temperatures, and therefore pest populations, are high. It is thought that when sowing of short-duration pigeonpea is delayed, the reproductive phase would coincide with the period of low temperature and hence low insect population. This study aims to:

- Determine the change in pest damage levels due to delayed sowing;
- Determine the extent to which delayed sowing reduces yield.

Methodology

Genotype. ICPL 87 or ICPL 86005.

Locations. Ilonga (low altitude), Gairo (medium altitude).

Design. Randomized complete block design, 2 x 3 factorial. Treatments: two spray regimes (spray, no spray). Four sowings—the first in Nov/Dec; and with the onset of the long rains, 3 sowings at 2-week intervals.

Expected Outputs

- Identification of the important pests of pigeonpea;
- Determination of damage levels;
- Recommendations on appropriate sowing dates.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	90	60
Operations		
Field inputs	138	140
Labor	96	60
Laboratory supplies	36	20
Communication	6	-
Reports and publications	24	20
Total	390	300

Response of Short-duration Pigeonpea to Spacing in Different Environments

Justification and Objectives

After several years of research on short-duration pigeonpea, ICPL 87 and ICPL 86005 have been identified as promising. It is believed that because of their shorter duration, they would do better in areas with low rainfall and where long-duration lines suffer from drought stress. However, a production package for this new crop has not been developed. Appropriate population density is not known; it must be determined for areas varying in moisture supply.

Methodology

Genotype. ICPL 87 or ICPL 86005.

Design. Complete randomized block design, 2 x 3 x 3 factorial. Spacing: interrow 40, 50, and 60 cm; within-row 20, 30, and 40 cm. Plants per hill 1 and 2.

Locations. Ilonga (wet, 500 m altitude), Gairo (moderately wet, 1000 m), Hombolo (dry, 1037 m).

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	135	90
Operations		
Field inputs	207	140
Labor	144	110
Laboratory supplies	54	30
Communication	9	10
Reports and publications	36	20
Total	585	400

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 (e.g., cowpea, beans, and green gram). Short-duration pigeonpea is being introduced into this cropping system as a potential replacement for other legumes. For such an introduction to be successful, trials are needed to determine the most appropriate intercropping pattern for pigeonpea with other crops.

Methodology

Location. Ilonga

Design. Randomized complete block design with 4 replications. 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	ICRISAT
Travel	30	-
Operations		
Field inputs	69	50
Labor	48	40
Laboratory	18	10
Communications	3	-
Reports and publications	12	10
Total	180	110

Germplasm Screening Against Fusarium Wilt

Justification and Objectives

Fusarium wilt is a major disease of pigeonpea in Tanzania, with incidence varying from 20 to 100% in farmers' fields. It is therefore critical to screen and identify lines resistant to the disease. The objectives 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	ICRISAT
Operations		
Field inputs	30	40
Labor	530	400
Laboratory supplies	20	140
Communication	-	50
Reports and publications	12	10
Total	592	640

Survey of Fusarium Wilt and Production/Marketing Systems

Justification and Objectives

Pigeonpea research in Tanzania is hampered by the 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 to survey the major production areas in northern and southern Tanzania to collect this information, which will provide a database for research and impact analysis.

Methodology

A multidisciplinary team of scientists and extension specialists will conduct the survey in the major pigeonpea-growing areas of Tanzania.

Budget

The budget for the survey is US$ 2260, of which $ 660 will be provided by NARS and $ 1600 by ICRISAT.

Processing of Pigeonpea

This study will comprise three aspects:

- Processing of vegetable pigeonpea;
- Processing of pigeonpea grain into *dhal;*
- Studies on cooking time for various varieties.

Budget

The budget for these studies is US$ 200 to be provided by ICRISAT, supplemented by NARS funding.

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 a short period. It is therefore necessary to develop a simple technology for processing green peas in rural areas so that the peas can be stored for longer.

Methodology

Treatments. Three dehydration treatments: blanched and dehydrated in the sun; blanched and dehydrated in a shed; blanched and dehydrated under a solar dryer.

Locations. Ilonga and Hombolo.

Processing of Pigeonpea Grain into *Dhal*

Justification and Objectives

Whole grain pigeonpea takes a long time to cook, and when stored it is susceptible to damage by insect pests. When dehulled, pigeonpea cooks quickly and stores well. The project aims both at promoting the utilization of pigeonpea as *dhal* and improving storability.

Methodology

Treatments. Dehulling at five moisture conditions.

Locations. Ilonga and Babati.

Cooking Time for Different Varieties of Pigeonpea

Justification and Objectives

Dry pigeonpea grain takes a long time to cook. The study aims to determine if variability exists in cooking time of whole grain. Such variability, if it is found, will be used in the breeding program.

Methodology

Treatments. Cooking for five durations: 30, 45, 60, 75, and 90 min.

Locations. Ilonga and Hombolo.

Staffing

NARS	ICRISAT
J.K. Mligo - Breeder	S.N. Silim - Agronomist
F.A. Myaka - Agronomist	S. Tuwafe - Breeder
A.M. Mbwaga - Pathologist	Laxman Singh - Breeder
A. Chilagani - Farming systems research and extension specialist	P. Subrahmanyam - Pathologist
S.T.P. Kunji - Food technologist	
J.A. Assenga - Breeder	

Tanzania Workplan Budget: ICRISAT Contributions[1]

	Funding (US$)
On-farm trials	1 300
Seed multiplication	800
Back-up research	
Long-duration varietal trial	800
Medium-duration varietal trial	800
Short-duration varietal trial	600
Sowing date trial	300
Spacing trial	400
Cropping systems trial	110
Screening for wilt tolerance	640
Survey of fusarium wilt and production/marketing systems	1 600
Processing studies	200
Total	7 550

1. Details of funding by the national program will be provided later.

Malawi Collaborative Research Workplan

The collaborative research workplan for Malawi involves

- On-farm trials;
- Seed multiplication;
- Back-up research;
- Survey of production, processing, and marketing systems;
- Human resource development.

On-farm Trials

Objectives

- To evaluate the performance of promising short- and medium-duration pigeonpea varieties on farmers' fields;
- To document farmers' perceptions of the varieties being tested;
- To determine the yield potential and adoption rates of the new varieties.

Methodology

Genotypes. QP 38, Royes, and ICPLs 151, 86012, and 87105.

Locations. Twenty-two farmers' fields in 8 agricultural development districts: Ngalen (Lower Shire Valley), Blantyre (Medium and Lower), Liwande (Lakeshore), Salima (Lakeshore and uplands), Lilongwe (medium altitude), Mzuzu (Medium and Upland Lakeshore), Karonga (Medium and Upland Lakeshore), and Kasongu (Medium and Upland Lakeshore)

Expected Outputs

- Increased farmer awareness of new pigeonpea varieties;
- Large increases in pigeonpea area once the new varieties are adopted.

Budget

The budget for these studies is US$ 8000, of which the national program will provide $ 5000, and ICRISAT $ 3000.

Seed Multiplication

Objectives

Lack of seed is a major constraint to the spread of released cultivars. The purpose of this project is to multiply and make available seeds of the most promising pigeonpea cultivars.

Methodology

Seed of five genotypes will be multiplied—QP 38, Royes, and ICPLs 151, 86012, and 87105. Each variety will be sown on 0.4 ha.

Budget

The budget for seed multiplication is US$ 3500, of which the national program will provide $ 2000, and ICRISAT $ 1500.

Back-up Research

The workplan covers back-up research on four aspects:

- Chemical control of insect pests;
- Varietal evaluation trials;
- Observation trial on cotton/pigeonpea intercropping;
- Screening against diseases.

Chemical Control of Insect Pests

Justification and Objectives

A number of insect pests attack pigeonpea (especially short-duration varieties), causing heavy losses. The study aims to develop economical methods for chemical pest control.

Methodology

Genotypes. Three cultivars: QP 38 (medium-duration), ICPL 87105 (short- duration, determinate), and ICPL 86012 (short-duration, indeterminate).

Treatments. Four pest control treatments. No spray; one spray at 50% flowering; two sprays (at 50% flowering and 10 days later); three sprays (at 50% flowering, and 10 and 20 days later).

Expected Outputs

- Development of control methods against insect pests;
- Increased productivity of pigeonpea.

Budget

The budget for pest control studies is US$ 1500, of which the national program will provide $ 1000, and ICRISAT $ 500.

Varietal Evaluation Trials

Justification and Objectives

Pattern and amount of rainfall vary in different regions of Malawi. Long-duration cultivars do well in areas where the growing season is long and the rainfall is well distributed. In the short-season areas, short-duration varieties do better. The aim of these trials is to evaluate various short-, medium- and long-duration pigeonpea varieties for their adaptability and yield in different agroecological zones, so as to provide farmers with different options from which to choose. Five trials are planned:

- Determinate short-duration trials (12 entries) at Ngabu, Chitala, and Baka;
- Indeterminate short-duration trial (12 entries) at Ngabu, Chitala, and Baka;
- Medium-duration yield trials at Ngabu, Chitala, and Baka;
- Long-duration yield trial (12 entries) at Chitala, Baka, and Makoka;
- Observation nursery.

Methodology

Each trial will have four replications. Each plot will have 4 rows, 6 m long, with ridges 90 cm apart. For short-duration varieties, two rows will be sown per ridge.

Intermediate Outputs

- Promising high-yielding cultivars will be identified for release or use in the national program.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	1 000	250
Operational costs		
Field inputs	1 000	500
Labor	1 500	250
Office supplies	100	
Total	3 600	1 000

On-farm Observation Trial of Cotton/Pigeonpea Intercropping

Justification and Objectives

In Malawi, long-duration pigeonpea is intercropped with cereals, mostly maize, and such other crops as cassava, sorghum, and cotton. With the introduction of short-duration pigeonpea, farmers may intercrop with other crops. It is believed that when cotton is intercropped with short-duration pigeonpea, the latter may benefit from the pesticides used on cotton. The study aims to determine:

- Whether intercropping pigeonpea with cotton is feasible;
- Whether there is variability among cultivars in their response to such intercropping.

Methodology

Two pigeonpea varieties of different maturity durations will be tested.

Expected Outputs

- Identification of the most suitable variety for intercropping with cotton.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel	500	500
Operational costs	300	200
Office supplies	100	-
Communication	100	-
Total	1 000	700

Screening Against Major Diseases

Justification and Objectives

In the 1979/80 growing season, there was a very serious outbreak of fusarium wilt, and all landraces were found to be susceptible. It is therefore essential to screen introduced lines for tolerance to wilt. Other diseases were also reported to affect pigeonpea, and we have started screening lines to select for tolerance.

Methodology

Single rows of pigeonpea lines will be screened.

Expected Outputs

- Selection and eventual release of wilt-tolerant lines.

Budget

The budget for the screening program is US$ 750, of which the national program will provide $ 250 and ICRISAT $ 500.

Survey of Production, Processing, and Marketing Systems

There is a lack of detailed information on pigeonpea production systems in Malawi, and on processing methods and marketing infrastructure (for both local and export markets). This study aims to collect data on these aspects for use in research planning and extension work.

Budget

The budget for the surveys is US$ 1000, of which the national program and ICRISAT will each provide $ 500.

Human Resource Development

The immediate training needs for the Malawi pigeonpea program have been identified. On this basis, training to M.Sc. level will be provided to three scientists, one each in agronomy/physiology, entomology, and pathology. In addition, three technicians will be provided in-service training.

Staffing

NARS	ICRISAT
Project staff	
H.N. Soko - Breeder	S. Tuwafe - Breeder
A. Likoswe - Agronomist	S.N. Silim - Agronomist
G.K.C. Nyirenda - Entomologist	P. Subrahmanyam - Pathologist
A.T. Daudi - Pathologist	V. Saka - Pathologist
Support staff	
C. Jambawe - Pathologist	
T. Kapewa	
J. Mchowa - Entomologist	

Malawi Workplan Budget: ICRISAT Contribution[1]

	Funding (US$) by ICRISAT
On-farm trials	3 000
Seed multiplication	1 500
Back-up research	
Pest management	500
Varietal evaluation	1 000
Agronomy (intercropping)	700
Disease screening	500
Surveys	500
Total	7 700

1. Details of funding by the national program will be provided later.

Uganda Collaborative Research Workplan

The collaborative research workplan for Uganda covers a variety of aspects:

- On-farm research;
- Back-up research;
- Back-up support activities;
- Postharvest studies;
- Processing and utilization studies;
- Human resource development.

On-farm Research

Objectives

- On-farm testing of four promising varieties (Kat 60/8 and ICPLs 86005, 87091, and 87101) at several locations;
- To document farmers' opinions of the promising varieties;
- To develop improved cropping systems (using pigeonpea as a rotation crop rather than an intercrop);
- To strengthen farmer-researcher-extension linkages.

Methodology

Four promising varieties will be tested on-farm during the first rains of 1994 in five districts of Uganda, namely Nebbi, Arua, Apach, Lira, and Gulu. These trials will be conducted in collaboration with nongovernmental organizations including CARE (at Nebbi and Arua), World Vision (Gulu), and ADP (Lira and Apach). Field days will also be organized.

Back-up Research

Back-up research will be conducted on breeding, agronomy, and crop protection The overall objective of these studies is to overcome the principal constraints to pigeonpea production and postproduction systems through collaborative and strategic research.

Breeding

The objectives are to:

- Develop high-yielding varieties acceptable to farmers;
- Develop cultivars resistant/tolerant to the principal abiotic and biotic stresses.

These objectives will be accomplished through the following experiments:

- Introduction from EARCAL of short-duration lines; collections from Uganda of medium- and long-duration lines; evaluation and selection of germplasm suitable for Uganda;
- Stabilization selection within the seed bulks;
- Multilocational yield testing.

Agronomy

The objectives are to improve agronomic practices to maximize yields and utilization of available resources, both on-station and on-farm. This will be done by:

- Determining the most appropriate sowing density for short-duration pigeonpea under different moisture environments. Locations are Lika and Kawanda; spacings of 30, 45, 60, and 70 cm will be used.
- Intercropping pigeonpea with finger millet;
- Intercropping/relay cropping pigeonpea with sugarcane.

Farmers will be involved in the research at one pilot village in Lira or Gulu district. They will participate in surveys, meetings, and on-farm experimentation, and work together with researchers on priority setting of the problems and identification of possible solutions.

Crop Protection

The objective is to reduce crop losses due to pests and diseases. This will be achieved through:

- Studies on range, distribution, and seasonality of pigeonpea field pests/diseases;
- Screening of pigeonpea varieties against field pests/diseases;
- Loss assessment studies.

Back-up Support Activities

Back-up support activities envisaged under the workplan are as follows.

- Seed multiplication. Bulking of quality seed is an important prerequisite to the adoption of new varieties. Seed of four promising lines/cultivars (Kat 60/8, and ICPLs 86005, 87091, and 87101) will be multiplied in Mar 1994;
- Establishment of sick plots for disease screening;
- Rearing of pests;
- Investigating management options against pests and diseases. The most serious field pests of pigeonpea are pod borers, pod-sucking bugs, and pod flies. The major diseases are cercospora leaf spot and fusarium wilt.

Postharvest Studies

Objectives

Broadly, the objective is to improve market value and availability of pigeonpea by reducing postharvest losses and thereby improving food security, especially among smallholder farmers. This will be addressed by:

- Investigating mechanisms of field infestation;
- Screening for resistance to field and storage pests;
- Investigating and formulating control strategies through the use of solar disinfestation, biorationals, oils, and specific control measures against storage pests.

Processing Research

Objectives

The aim of the project is to add value, increase utilization, and improve the marketing of pigeonpea. This will be done through:

- Development of processing technologies for rural-based dehulling and medium-size processors;
- Evaluation of technologies.

Socioeconomic Factors

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.

Human Resource Development

Training needs for research staff and technicians are an important aspect of project activities. Three researchers will be supported for training in agronomy (to PhD level), breeding (PhD), and economics (BSc). In addition, 10 technicians will be provided short-term training; in food processing (2 trainees), agronomy (2 trainees), and general computer skills (6 trainees).

Staffing

NARS	ICRISAT
M.S. Musaana - Breeder	S.N. Silim - Agronomist
M.A. Ugen - Agronomist	Laxman Singh - Breeder
T.E.E. Areke - Breeder	S. Tuwafe - Breeder
M.S. Nahdy - Entomologist	ICRISAT entomologist
F. Opio - Pathologist	S.B. King - Pathologist
J. Njogedde - Breeder	ICRISAT socioeconomist
	U. Singh - Food technologist

Uganda Workplan Budget: Government of Uganda Contribution

	Funding (US$)
Salaries and incentives	20 400
Transport and vehicle maintenance	2 000
Top-up fuel	1 500
Office and staff accommodation	10 200
Land and tractor use	1 000
Utilities	1 000
Materials and supplies	500
Total	36 600

Uganda Workplan Budget: ICRISAT Contribution

	Funding (US$)
On-farm research	
Travel and allowances	2 000
Overtime payment to extension agents	500
Supplies and field inputs	1 000
Back-up research	
On-station activities (land preparation, sowing, weeding, harvesting, threshing, sorting)	2 500
Materials and supplies	500
Back-up support activities (seed multiplication, insect rearing, publications and reports)	1 000
Total	7 500

Sudan—Collaborative Research Workplan

The collaborative research workplan for Sudan involves the following studies:

- Varietal evaluation trials;
- Demonstration plots and seed multiplication;
- Agronomy research;
- Studies on postharvest technologies.

Varietal Evaluation Trials

Justification and Objectives

Pigeonpea is grown on an estimated 15 000 ha in the irrigated areas of central and northern Sudan. The crop is grown as a wind-break, but has the potential to replace lentils in *dhal.* Pigeonpea can be introduced in the rainfed areas of western and eastern Sudan. In the Gezira area it is possible to expand the area under pigeonpea. In the semi-mechanized areas of eastern Sudan, where sorghum is grown year after year, the project aims at introducing pigeonpea in the rotation.

Methodology

Trials will be conducted for both short- and medium-duration varieties. For each duration group, yield and biomass of different varieties will be compared in each of the production systems.

Intermediate Outputs

Promising high-yielding cultivars will be identified for release.

Budget

	Funding by ICRISAT[1] (US$)
Travel	300
Operational costs	
Field inputs	500
Labor	400
Communications and supplies	100
Total	1 300

1. Details of funding by the national program will be provided later.

Demonstration Plots/Seed Multiplication

Justification and Objectives

Previous results have shown that short-duration pigeonpea has potential, particularly in the irrigated areas of the Sudan. Some widely adapted lines are available, but need to be sown on large plots for demonstration and seed multiplication.

Methodology

Two to four promising lines will be grown on large plots in the Gezira area. Data will be collected on yields and production costs. Depending on the success of the crop, a field day may be organized.

Budget

	Funding by ICRISAT[1] (US$)
Field inputs	400
Labor	300
Total	700

1. Details of funding by the national program will be provided later.

Agronomy

The following trials will be conducted:

- Intercropping trials in western Sudan;
- Sowing density trials in western Sudan;
- Trials to evaluate the potential of pigeonpea in agroforestry systems and for forage in western Sudan;
- Sowing date trials in Gezira;
- Seeding density trial in Gezira.

Budget

	Funding by ICRISAT[1] (US$)
Travel	250
Operational costs	
Field inputs	400
Labor	300
Office supplies, communication, and reports	50
Total	1 000

1. Details of funding by the national program will be provided later.

Postharvest Technologies

Pigeonpea is traditionally grown in central and northern Sudan and eaten as whole boiled grain, particularly during the month of fasting. Lentil is grown in northern Sudan during winter and consumed as *dhal,* but demand for lentil is higher than production and prices are extremely high. Split pigeonpea could therefore partially substitute or complement lentil in Sudan, particularly since a dehulling industry exists.

The Food Research Centre will conduct trials on:

- Storage and handling of pigeonpea;
- Processing and utilization.

Storage and Handling

A survey of current storage practices will be conducted, and data collected on storage conditions, storage problems, and storage pests. The progressive biochemical changes during storage and handling will be analyzed in the laboratory.

Expected outputs. Recommendations will be developed, based on the survey and laboratory studies, on appropriate storage methods for pigeonpea.

Processing and Utilization

One way of catalyzing pigeonpea production is to broaden its utilization base, e.g., by increasing the production of dehulled pigeonpea for use as split peas. The promotion of pigeonpea consumption also requires the development of new products. The following studies will be conducted:

- Analysis of promising pigeonpea lines to determine their nutritive value;
- Cooking tests to determine optimal cooking conditions (temperature, time, pre-conditioning, etc.);
- Processing studies to determine the best form of dehulling, and identify grain characters that would improve dehulling properties;
- Development of new pigeonpea products as substitutes for chickpea and faba beans;
- Promotion and marketing through demonstration and extension.

Collaboration with other regional research units. The Food Research Centre is well developed, with adequate trained staff and facilities. We can help countries in the region to analyze samples and conduct laboratory tests.

Budget

	Funding by ICRISAT[1] (US$)
Chemicals	500
Seed, etc.	300
Total	800

1. Details of funding by the national program will be provided later.

Staffing

NARS	ICRISAT
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Sitt el Naffar M. Badi - Food technologist	Laxman Singh - Breeder
M.A.H. Khair - Agronomist	Consultant - Processing

Sudan Workplan Budget Summary: ICRISAT Contributions[1]

	Funding by ICRISAT (US$)
Varietal evaluation trials	1 300
Demonstration/seed multiplication	700
Agronomy	1 000
Postharvest technologies	800
Total	3 800

1. Details of funding by the national program will be provided later.

Zambia—Collaborative Research Workplan

The collaborative workplan for pigeonpea research in Zambia involves **the following** areas:

- On-farm research;
- Back-up research;
- Human resource development.

On-farm Research

Justification and Objectives

The Food Legumes Research Team has identified medium-duration pigeonpea genotypes from varietal evaluation work. These lines are different from the local landraces normally grown by farmers. On-farm trials are now needed to evaluate their performance and obtain farmers' assessments of their suitability.

Methodology

Genotypes. Four varieties: 3 improved medium-duration varieties (IGP 7035, 423/50/3, and HY 3C) and one local landrace (ZCC 17) as a control.

Locations. Four target areas in Eastern Province, with four farmers per area.

Data. Agronomic characters and pest/disease reactions; farmers' comments on the varieties (through interviews).

The ICRISAT regional breeder and agronomist should visit all on-farm trials at least once during the season.

Expected Outputs

- Farmer awareness and subsequent acceptance of improved varieties;
- Release of improved varieties for commercial production.

Budget

	Funding (US$) by	
	NARS	SADC/ICRISAT
Travel (in-country)	1 500	500
Operations		
Field inputs	250	250
Labor	1 250	750
Total	3 000	1 500

Back-up Research

These studies involve evaluation trials of pigeonpea varieties from different maturity groups. The following trials will be conducted:

- Determinate extra short duration trial (2 sets);
- Indeterminate short-duration trial (2 sets);
- Regional short-duration trial (2 sets);
- International medium-duration trial (1 set);
- International long-duration trial (I set);
- Regional long-duration trial (2 sets);
- Long-duration observation nursery (2 sets);
- On-farm trial of 5 lines (2 short- and 3 medium-duration) identified for Malawi.

Justification and Objectives

The Zambian agricultural policy, which earlier focused on maize promotion, now emphasizes crop diversification to improve national and household food security. There is also more emphasis on the generation of sustainable technologies. Pigeonpea fits very well into these roles: extra short and short-duration types can provide food during the 'hunger period' when most crops are not ready for harvest. Export demand is high, and the crop is thus a good potential source of foreign exchange. The inclusion of pigeonpea in cropping systems will improve soil fertility, which is a prerequisite to ensuring sustainability of food production. Lastly, pigeonpea has multiple uses in agroforestry, research on which is now receiving considerable attention in Zambia.

These trials are being conducted with two main objectives:

- To identify pigeonpea genotypes suitable for production in the three major agroecological zones in Zambia;
- To identify pigeonpea genotypes for use in different agroforestry systems.

Methodology

All pigeonpea test entries in the trials are provided by the ICRISAT regional program. The trials will be sown at Msekera and Golden Valley Research Stations in randomized complete block designs with four replicates.

Expected Outputs

Intermediate. After 3 years of testing at Msekera and Golden Valley Research Stations, promising genotypes will be evaluated at sites representing the three agroecological zones in the country.

Final. Two varieties per zone will be tested on-farm for eventual release.

Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel		
In-country	500	250
Regional	500	
Operations		
Field inputs	500	250
Labor	1 200	500
Total	2 700	1 000

Human Resource Development

The immediate training needs for the Zambian national program have been identified. On this basis, two technicians will be provided in-service training, and one scientist (agronomy) will be supported for a PhD.

Staffing

NARS	ICRISAT
K. Kanenga - Agronomist	S. Tuwafe - Breeder
J. Mulila-Mitti - Breeder	S.N. Silim - Agronomist
R. Raussen - Agronomist	P. Subrahmanyam - Pathologist
K. Muimui - Breeder	ICRISAT entomologist
Extension staff	

Zambia Workplan Budget Summary: ICRISAT Contributions[1]

	Funding (US$)
On-farm trials	1 500
Back-up research	1 000
Total	2 500

1. Details of funding by the national program will be provided later.

Mozambique—Collaborative Research Workplan

Background and Objectives

Pigeonpea is an important crop in Mozambique. Long- and medium-duration cultivars are traditionally used; yield data are unavailable, but harvests are believed to be adequate. Pigeonpea research first started in 1992. The current objectives of the project are to:

- Collect local germplasm from the main production areas;
- Evaluate, purify, characterize, and maintain local germplasm.
- Evaluate lines supplied by ICRISAT.

Methodology

A systematic varietal screening program is planned, the results of which will be used for varietal improvement. Both locally collected and introduced germplasm will be evaluated. The planned duration for these studies is—collection and characterization: 2 years; evaluation and purification: 5 years. The regional pigeonpea breeder, agronomist, and pathologist should visit Mozambique to assist in these studies.

Training

Training needs to be provided to research and support staff. The workplan envisages short training courses for technicians and longer courses for research assistants.

Staffing

NARS	ICRISAT
J. Arias-Fondion	S. Tuwafe - Breeder
Marcela Libombo	S.N. Silim - Agronomist
Baciao Silva	P. Subrahmanyam - Pathologist

Mozambique Workplan Budget

	Funding (US$) by	
	NARS	Pigeonpea Project
Travel (in-country)	500	1 500
Operations	1 000	-
Field inputs	500	500
Labor	1 000	-
Laboratory supplies	100	-
Communication	300	-
Reports and publications	50	100
Total	3 450	2 100

Swaziland—Collaborative Research Workplan

Justification and Objectives

Research on pigeonpea was conducted in the early 1970s in Swaziland on long-duration (7-8 months to maturity) and short-duration (4-6 months) germplasm. These studies produced no conclusive results. However, there were indications that the crop is dual-purpose (providing both grain and fodder), drought-tolerant, and can be used to improve soil fertility through green manuring and nitrogen fixation. This would reduce farmers' expenses on inorganic fertilizers and soil amendments. The aims of this study are to:

- Screen and identify adapted cultivars with high yield and insect/disease tolerance;
- Identify cultivars acceptable to both consumers and producers.

Methodology

One set from each maturity group will be sown at Luve (Dry Middleveld). Plot sizes and management practices will be specified by the ICRISAT/AfDB Pigeonpea Project. There are currently no standard management recommendations for this crop in Swaziland; ICRISAT regional pigeonpea scientists should therefore visit the country to help NARS staff assess the crop.

Expected Outputs

- Identification of high-yielding cultivars acceptable to producers and consumers;
- Promotion of commercial pigeonpea production;
- Identification of external markets once sufficient production potential is established.

Human Resource Development

Four research staff will be supported for higher studies: agronomy, to PhD level; agronomy, to BSc level; pathology (MSc); and entomology (PhD). In addition, short-term courses are proposed: food technology and processing (1 trainee) and a training course for technicians (1 trainee).

Staffing

NARS	ICRISAT
Z. Mamba - Agronomist	S. Tuwafe - Breeder
E. Nzumalo - Agronomist	S.N. Silim - Agronomist
M. Nsibanda - Entomologist	P. Subrahmanyam - Pathologist
K. Mabuza - Food technologist	ICRISAT entomologist

Swaziland Workplan Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel (in-country)	200	300
Operational costs		
Field inputs (bags, tags, etc.)	200	200
Labor	2 000	800
Total	2 400	1 300

Namibia--Collaborative Research Workplan

The collaborative research workplan for Namibia deals essentially with the evaluation of pigeonpea lines for their potential in the country.

Justification and Objectives

Farmers in drought-prone northern and central Namibia depend mainly on pearl millet, which is suitable for the degraded, low-nutrient soils in these regions. Pigeonpea is not grown in Namibia. However, it has potential for introduction, being drought-tolerant and a good soil amendment. Because of its high protein content, it is also a good diet supplement, especially for the rural poor. The aims of the study are to:

- Determine the potential of pigeonpea as a food/cash crop;
- Evaluate extra short, short-, medium-, and long-duration pigeonpea for adaptation to Namibian conditions;
- Select the most suitable cultivar/duration group for introduction.

Methodology

Four nurseries/trials will be obtained from the ICRISAT regional pigeonpea program—extra short, short-, and medium-duration pigeonpea nurseries, and a long-duration pigeonpea trial. All production packages will be developed by ICRISAT scientists, who are expected to visit the trials at least once.

Locations. Uitkmost, Mohana.

Data. Phenology, yield and yield components, pest and disease reactions.

Staffing

NARS	ICRISAT
D. Marais - Agronomist	S. Tuwafe - Breeder S.N. Silim - Agronomist ICRISAT entomologist

Namibia Workplan Budget

The workplan budget for Namibia is US$ 1000, of which the national program will contribute $ 700, and ICRISAT $ 300.

Lesotho—Collaborative Research Workplan

Background and Justification

Maize is the staple food in Lesotho, but crop failures are common, due mainly to frequent droughts and continuous maize-maize cropping systems. There is a need to introduce a new legume crop such as pigeonpea which can withstand drought and improve both soil fertility and nutrition. Pigeonpea is new to Lesotho and it is important to screen short- and medium-duration varieties to determine whether they fit into the cropping system. Short-duration crops are generally preferred by farmers because of the climate; warm, short summers with limited rainfall and long, cold winters.

Methodology

An on-station observation trial will be conducted at two locations (possibly Maseru and Leribe) representing lowland areas. The trial will be managed and implemented by researchers. Sixteen varieties will be tested, with two replicates.

Data. Phenology, yield and yield components, pest and disease incidence, and weather data.

Expected Outputs

- Observation and selection of superior pigeonpea lines for further testing;
- On-farm testing and evaluation of promising materials;
- Recommendations on materials evaluated on-farm;
- Organization of seed multiplication schemes;
- Improved processing and utilization of pigeonpea.

Staffing

NARS	ICRISAT
S.S. Moima - Breeder	S. Tuwafe - Breeder
S. Molupe - Support staff	S.N. Silim - Agronomist
L. Semathane - Support staff	P. Subrahmanyam - Pathologist

Lesotho Workplan Budget

	Funding (US$) by	
	NARS	ICRISAT
Travel (in-country)	150	80
Operational costs		
Field inputs	100	100
Labor	500	100
Reporting and communication	200	20
Total	950	300

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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 18 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 World Bank, and the United Nations Development Programme (UNDP).

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