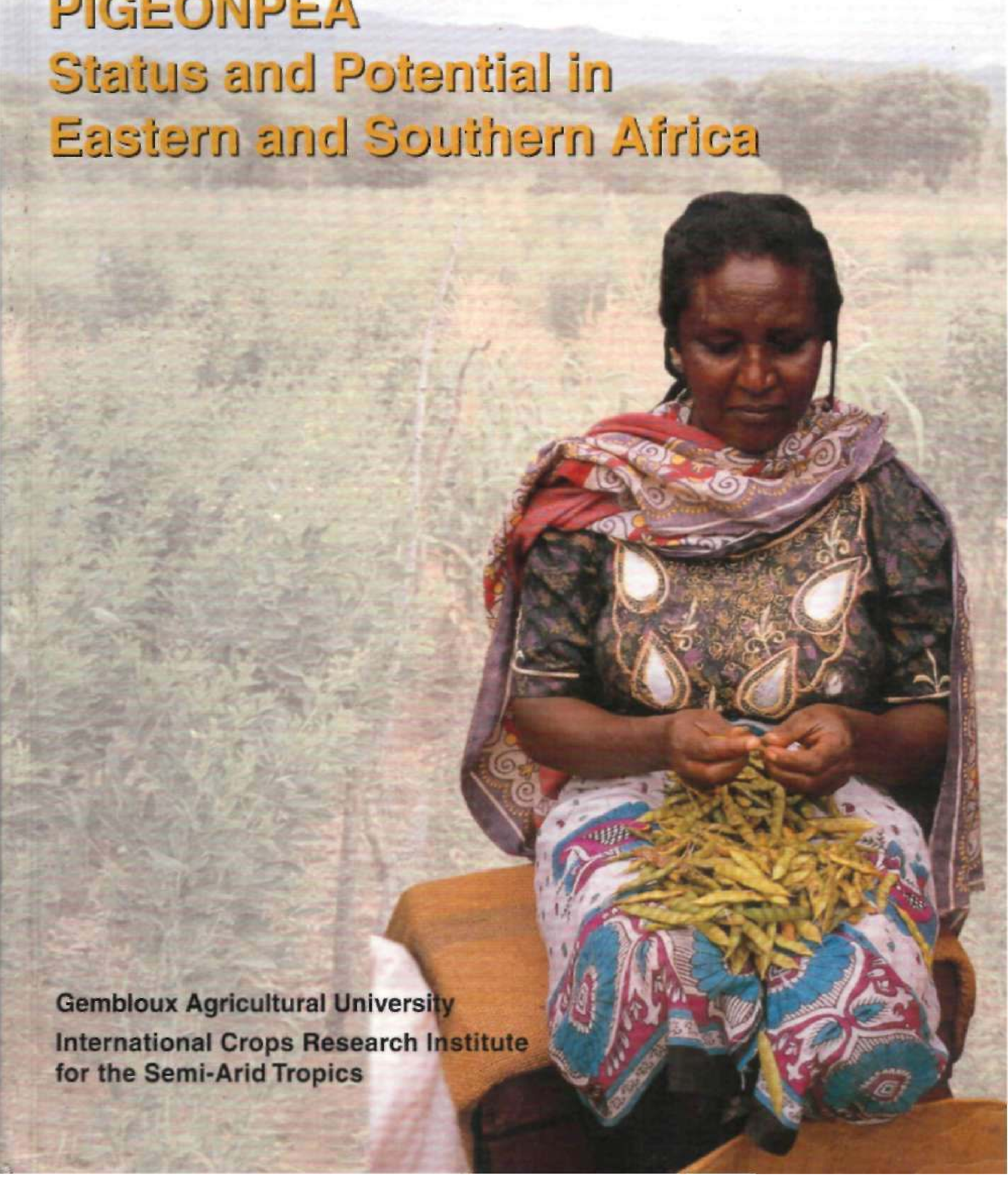
PIGEONPEA
Status and Potential in Eastern and Southern Africa



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for the Semi-Arid Tropics

Citation. Silim, S.N., Mergeai, G., and Kimani, P.M. (eds) 2001. Status and potential of pigeonpea in Eastern and Southern Africa: proceedings of a regional workshop, 12-15 Sep 2000, Nairobi, Kenya. B-5030 Gembloux, Belgium: Gembloux Agricultural University; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 232 pp. ISBN 92-9066-432-0. Order code CPE 130.

Abstract

Pigeonpea is a multipurpose, multi-benefit crop adapted to semi-arid conditions, and an important component of traditional intercropping systems in eastern and southern Africa. This publication contains presentations, discussions, and recommendations from a workshop to review the current status and future prospects for pigeonpea in the region. The workshop, held in Nairobi in Sep 2000, attracted 29 participants from six countries, representing various stakeholder groups including national and international research institutes, universities, NGOs, and policy makers.

A range of improved technologies is available. Efforts to improve adoption must center on commercialization of pigeonpea, i.e. providing smallholder farmers with reliable market outlets, market information, and adequate incentives to invest in productivity-enhancing technologies. Participants suggested the following: (i) Consolidate research information (currently scattered in journals and reports) into a comprehensive technology inventory for the region, identify gaps in knowledge. (ii) Identify specific markets, package available technologies (variety, management) for each of these markets, establish links with marketing agencies where possible. (iii) Initiate studies to collect additional information, particularly on market opportunities, transaction costs, and comparative advantages.

Status and Potential of Pigeonpea in Eastern and Southern Africa

Proceedings of a Regional Workshop
Nairobi, Kenya, 12-15 Sep 2000

Edited by

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This publication and the regional workshop were co-sponsored by the Gembloux Agricultural University, Belgium with support from the Conseil Interuniversitaire de la Communauté Française de Belgique and the European Union. Much of the work presented was co-funded by the European Union under the project "Genetic improvement of pigeonpea and management of intercropping systems in the semi-arid areas of East Africa" (contract no. ERBICIC 18CT 960130).

Contents

Inaugural Session

Welcome Address

S N Silim[1]

Dr Kiome, Director General of KARI; Prof Mukunya, Principal, College of Agriculture and Veterinary Medicine, University of Nairobi; ladies and gentlemen:

Welcome to Nairobi - *karibuni,* as we say. Many of you have traveled long distances, taking time off your busy schedules, to be here today. Thank you for your support. I hope your journey was pleasant, and that you find the celebrated Nairobi weather stimulating (but not too stimulating). We are here for this important workshop which has two major objectives - first, to review the results achieved in the past few years; and second, identify a future course of action to build on past achievements.

Let me begin with a brief background. ICRISAT has a global mandate for research and improvement of pigeonpea. The world's largest pigeonpea producer is India, where ICRISAT's headquarters are located. But five of the top six producers are in eastern and southern Africa, where pigeonpea has been grown for perhaps 4000 years. The crop is drought-tolerant, it provides multiple benefits, it can give good yields even with limited inputs - but simultaneously it is also a potential cash crop. It thus directly benefits our primary client - the resource-poor smallholder farmer, who operates in a variable, semi-arid environment and generally lacks access to technology, cash, and other resources. I believe all of us share the same mandate - to develop and promote technology aimed at the smallholder farmer. Pigeonpea fits well into the smallholder agricultural and economic system. And this workshop aims to find ways to leverage this intrinsic "good fit" into more diversified cropping opportunities, higher farm incomes, and a more sustainable farming system.

In 1992, the African Development Bank provided funding for the Pigeonpea Improvement Project for Eastern and Southern Africa. The project operated in 10 countries, implemented by a broad network of partners - national research institutes such as KARI, NGOs such as TechnoServe and Catholic Relief Services, the private sector, advanced research institutes, extension services, and farmer groups. This network of partnerships has generated impressive results.

Several improved varieties have been released, including short-duration varieties suitable for cash-cropping. Pest and disease control methods have been developed. Physiology and adaptation studies have greatly improved the targeting of varieties to specific environments. But the project's single biggest contribution has probably been in the area of capacity building. Before 1992, Kenya was the only country in the region with an active pigeonpea research program. Today, 10 countries have established R & D programs. The number of scientist-years in the region has increased five-fold since 1992. Scientists and other researchers have been sponsored for higher education. Training programs have been conducted in several countries for food technologists, manufacturers of processing equipment, farmers, and specifically women.farmers (processing and utilization techniques).

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Simultaneously, the project has brought together a number of partners with complementary skills and expertise, to improve the dissemination of new pigeonpea technologies. For example, private-sector millers in Malawi and Kenya are helping us develop commercial marketing channels. As a result, we are now in a position to take on new challenges, in both research and technology dissemination.

I must express our gratitude to the various co-sponsors who made this meeting possible - the Kenya Agricultural Research Institute (KARI), ICRISAT, European Union (INC-DEV Programme), Conseil Inter-universitaire de la Communaute francaise de Belgique (CIUF), Makerere University, and the Universities of Nairobi, Gembloux, and Bonn. Equally important are our partners in KARI and other research institutes who led the research efforts. You will all agree that pigeonpea is a crop with enormous potential. I believe we have the technology, the collective experience, and the commitment to help realize this potential. I hope we will be able during this workshop to outline a set of concrete steps to promote pigeonpea cultivation and commercialization throughout the region.

Thank you.

Opening Address

R Kiome[1]

Ladies and gentlemen

Thank you for your invitation; it is a pleasure to be here today to discuss R & D strategies for one of the most important legume crops in the region.

I am familiar with ICRISAT's work on legumes and cereals. The Kenya Agricultural Research Institute (KARI) has always been a strong supporter of pigeonpea research programs because of the importance of the crop. Last August, I toured Machakos District and other parts of Eastern Province, where pigeonpea was the only crop that survived and produced grain. Two consecutive droughts have caused great hardship to farmers, especially smallholders; and the advantages of growing drought-tolerant crops are more evident than ever. The benefits of drought tolerance in pigeonpea are widely recognized. But this aspect has not been sufficiently emphasized by the research community, or by policy makers, in order to promote pigeonpea. In addition to the many other benefits this crop provides, we must emphasize its advantages as an "emergency" crop, capable of providing food in drought situations. Perhaps we need to lay greater emphasis on this aspect even in breeding and agronomy research.

Good work has been done on variety improvement, but some challenges remain:

Adoption. Adoption rates are poor, despite the significant yield improvements that the new varieties offer. Pigeonpea has not been able to compete with other crops, especially cash crops. We need to address these issues, and devise ways to increase adoption and impact of new technologies.

Socio-economic factors. The farmer is interested in food supply and cash, not in any particular crop. Decisions are made based on cash, labor and other inputs needed, and the returns from investment in inputs. Thus, we need to examine the cost-effectiveness of pigeonpea production, and offer farmers economically advantageous options. More information is needed on various aspects - impact assessments, adoption surveys, socio-economic factors such as resource availability, market access and so on. Farmer-participatory studies in these areas will help document the advantages of pigeonpea and identify specific traits (e.g. vitamin content) that can be improved, for example using biotechnology.

Systems approach. One unfortunate aspect of many crop improvement programs is that the sorghum breeder tries to promote sorghum, the pigeonpea breeder emphasizes the advantages of pigeonpea, and so on. Rather, we need a systems approach. Research programs must determine how well any potential variety or technology fits into the cropping system.

Future projections. What are the projections for future expansion/adoption, what is pigeonpea's comparative advantage relative to other crops? It clearly has an adaptive

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advantage in semi-arid areas; how can we build on this advantage to promote the crop more widely? We must remember that this advantage may not last indefinitely. For example, breeders are now trying to develop drought-tolerant maize, which could challenge pigeonpea's dominance in dry areas. Simultaneously, we must ensure that our own research remains cost-effective and relevant to farmers' needs.

KARI strongly supports ICRISAT's pigeonpea work, evidenced by the presence of KARI scientists at this meeting, and their close association with the pigeonpea project over the years. I note there are participants from Uganda and Tanzania as well, indicating that other countries in the region (e.g. ASARECA members) are supportive of these efforts to improve food security in eastern and southern Africa. KARI will continue to support ICRISAT's efforts to promote pigeonpea. The crop is very much a part of traditional cropping systems; it has wide consumer acceptance, it is adapted to conditions in the region, and can offer both food security and cash income. Working together, we can build on these inherent advantages to improve the technology options available to smallholder farmers throughout the region.

I am sure this meeting will lead to the development of a clear strategy for pigeonpea research and dissemination in the future, and that agricultural development in the region will benefit as a result. I now officially declare this workshop open.

Thank you.

Approaches to Pigeonpea Research

D M Mukunya[1]

Ladies and gentlemen

Thank you for giving me the opportunity to attend this meeting, and interact with legumes scientists from a range of disciplines. I think I know most of you already, and we have worked together in the past. I began my academic career with the University of Nairobi, working with grain legumes -I can say without exaggeration that my heart belongs to grain legumes.

I recently toured the Eastern and Central Provinces. Crops have been devastated after two seasons of severe drought, and even weeds were struggling! The only green thing we could see in the fields was pigeonpea, thanks to its drought tolerance.

Pigeonpea research in the region has been fairly successful. A number of improved varieties have been either released or are under advanced on-farm testing in several countries. In Kenya, we have lines such as NPP 670 and Kioko, developed by Onim, Kimani, and others; Kat 60/8 developed by Omanga; and several other lines developed or introduced by ICRISAT. This represents very hard work over a long period - such persistence in research is important, especially in a semi-arid environment like ours, where replicability of conditions is so difficult.

If we have been successful, it is in large measure due to collaboration with different partners. We began collaboration many years ago - that is why we survived. Collaboration was developed through various avenues. First, between organizations in Kenya - for example, KARI and the University of Nairobi work together, as we should. We target the same farmer, so we need to work together as one institution, and forge even closer links. We sent students to ICRISAT-India for MSc and PhD degrees through an informal Memorandum of Understanding, and training activities expanded greatly after ICRISAT established an office in Nairobi. The European Union (notably Belgium and Germany) also provided some funding. We have long worked with national programs in the region as well -in fact, Kabete Research Station, one of Kenya's oldest, belongs to Makerere University in Uganda! This synergy is important, because with synergy, 1 plus 1 makes 3.

Future research must build on these achievements and partnerships. If we are to aim for new technologies and new varieties, we need clear objectives, a pro-active approach, and long-term commitment from all partners.

Research facilities in Kenya are sadly lacking. Lack of funding means that it is difficult to procure new equipment, and often even to maintain existing facilities. By collaborating we get not only ideas and expertise from our partners, but also access to equipment and facilities.

Let me thank you all for your work, and your approach to agricultural development; and in particular, ICRISAT, KARI, and Gembloux University, who made this meeting possible.

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Technology Development

Strategies and Experiences in Pigeonpea Variety Development for Eastern and Southern Africa

S N Silim[1]

Introduction

Pigeonpea is one of the major grain legume crops grown in the tropics and subtropics. It is usually grown rainfed in areas prone to drought. In these areas, day length varies from 11 to 14 h and large differences in temperature are experienced, largely due to variations in altitude and latitude. The traditional varieties grown are mainly medium- and long-duration types, which are intercropped with cereals such as maize and sorghum and various short-duration legumes such as cowpea and beans (Ali 1990, Silim et al. 1991). These traditional varieties are extremely sensitive to photoperiod and temperature, with plant height, vegetative biomass, phenology, and grain yield being the traits most affected (Byth et al. 1981, Whiteman et al. 1985). The sensitivity of pigeonpea to temperature and photoperiod is a major constraint to the development of stable and predictable management practices, cropping systems, and varieties (Whiteman et al. 1985). Concerted research efforts by ICRISAT and its partners have resulted in the development of extra-short and short-duration varieties that escape drought and are less sensitive to photoperiod than traditional medium- and long-duration types (Singh et al. 1990). This has increased the flexibility of pigeonpea cultivation and facilitated its use in different cropping systems (Nene 1991).

ICRISAT's efforts to develop photoperiod-insensitive extra-short and short-duration varieties have unwittingly resulted in the development of varieties adapted to warm temperatures (Omanga et al. 1995) and sensitive to low temperature. For example, attempts in 1990 and 1991 by ICRISAT to introduce short-duration pigeonpea in rotation with wheat in the highlands of Kenya, where temperatures are cool, were not successful because the low temperature caused a delay in pigeonpea phenology and hence interfered with the cropping sequence.

During the initial stages of the Pigeonpea Improvement Project for Eastern and Southern Africa, we realized that the requirements for pigeonpea varieties are specific to the region. Varieties in eastern and southern Africa show a different adaptation from those in the Indian sub-continent. Medium- and long-duration varieties developed at ICRISAT-Patancheru in India and which have shown potential there, often performed poorly and were not always well adapted to the region. Large, cream and speckled grains are preferred in the region whereas small to medium-sized brown grains are the common types in India. A regional approach was therefore required to ensure that varieties developed are adapted to the region and meet end user requirements.

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Influence of Temperature and Photoperiod on Adaptation

Five strategic locations in Kenya were used, representing both traditional (Katumani, Kiboko) and non-traditional (Mombasa, Kabete, Muguga) pigeonpea-growing areas. Altitude at the experimental sites varied from 50 m to about 2100 m, with corresponding variation in temperature (Table 1). Latitude ranged from 1°10' to 4°25' S. There were three light treatments: natural daylength (about 12.6 h) at all locations, and artificially extended daylength of 14.5 h (Kiboko, Katumani, Kabete) and 16 h (Kiboko and Kabete). Daylength was extended by using 100 W incandescent bulbs suspended 2 m above the ground and 1.5 m apart. The daylength treatments were sited at least 50 m from each other. This approach allowed us to understand the influence of temperature and photoperiod on crop phenology and yield, and thus target varieties to areas of their best adaptation.

Determination of germplasm for suitability. A large number of germplasm lines from the region, accessions from the ICRISAT genebank, and improved varieties developed mainly by ICRISAT in India were evaluated at Kiboko under natural daylength to select lines with acceptable grain characteristics. The test material was drawn from all maturity groups, extra-short, short-, medium- and long-duration. This approach allowed us to exclude lines with unacceptable grain traits, mainly small (100-seed mass <10 g) brown grains, and also reduce the number of accessions to manageable levels.

Modulation of phenology by temperature and photoperiod. Germplasm, improved varieties, and accessions from different parts of the world in each duration group were grown at five locations (Table 1) to determine their performance under varying temperature and photoperiod. We measured environmental effects on phenology, the most important being time taken to a particular event. Summerfield et al. (1991) described a series of models used to predict phenological events (flowering in this case) not as time to flower (f) but rates of

Table 1. Latitude, altitude, long term temperatures and rainfall at 5 study sites, Kenya.

Location	Latitude (S)	Altitude (m)	Season*	Temperatures (°C) Max	Min	Mean	Rainfall (mm)
Mombasa	4° 25'	50	SR	31.4	23.2	27.3	370
			LR	28.9	21.5	25.2	679
Kiboko**	2° 20'	900	SR	29.4	17.7	23.5	464
			LR	27.8	15.5	21.6	140
Katumani	1°35'	1560	SR	25.6	14.4	20.0	467
			LR	23.6	12.9	18.2	244
Kabete	1°15'	1825	SR	24.6	12.9	18.7	478
			LR	22.1	12.2	17.1	518
Muguga	1°10'	2100	SR	21.9	11.5	16.8	461
			LR	19.5	10.1	14.9	500

* SR = Short rains (Oct-Feb); LR = Long rains (Apr-Sep)

** Received supplemental irrigation

progress towards flowering (i.e. 1/f, the reciprocal of the time taken) as influenced by photoperiod and temperature. The temperature range in which plant growth and development occurs is characterized by a base temperature T_b below which the rate of development is zero, an optimum temperature T_o at which the rate of development is most rapid, and a warmer ceiling limit T_{ce} beyond which development again ceases (Summerfield et al. 1991). Similarly, for short-day plants such as pigeonpea, flowering response to photoperiod is defined by the critical photoperiod P_c, which is the daylength beyond which flowering is delayed. With further increase in daylength, a ceiling photoperiod P_{ce} is reached, when days to flowering reaches a maximum (Summerfield et al. 1993). Rates of progress from sowing to flowering were calculated as 1/f for each variety, using the protocol developed by Summerfield et al. (1991).

Use of the model made it easy to define the adaptation of pigeonpea. It showed that the area where the germplasm was collected or the variety was developed has a strong influence on adaptation of the plant (Table 2). The study led to the following conclusions. The groups are listed in decreasing order of sensitivity to temperature:

Table 2. Influence of temperature on phenology of pigeonpea of different duration groups, Kenya.

	Days to 50% flowering				
	Muguga	Kabete	Katumani	Kiboko	Mombasa
Extra short duration	88	90	76	60	80
Short duration	90	85	80	62	80
Medium duration	125	117	112	96	127
Long duration	120	125	140	240	Did not flower

- Extra-short-duration varieties developed by ICRISAT- Patancheru in India (17°N, 78°E, 500 m elevation) were the least sensitive to photoperiod and had the highest T_o of 26°C. Time to flower and mature is delayed by cool temperature; this group is the most sensitive to low temperature.
- Short-duration varieties developed by ICRISAT-Patancheru are relatively insensitive to photoperiod and had a high T_o of about 24° C. Time to flower and mature is delayed most by cool temperature.
- Medium-duration germplasm or varieties from low-elevation areas near the equator are sensitive to daylength and will flower only under short photoperiod. The optimum temperature for early flowering is about 24°C. This sensitivity to photoperiod means that medium-duration varieties, if planted away from the equator, will flower only when daylength is short, i.e. towards autumn.
- Medium-duration varieties developed by ICRISAT-Patancheru or in peninsular India are sensitive to photoperiod. Optimum temperature for early flowering is about 22°C. Like the previous group, these varieties, if planted away from the equator, will flower only when daylength is short.

- Long-duration germplasm or varieties from near the equator or subtropics are sensitive to daylength and will flower only under short photoperiod. The optimum temperature for early flowering is about 18°C. These varieties are best suited to medium to high elevation near the equator, and areas in the subtropics where daylength is short and temperatures are low during winter.
- For long-duration germplasm or varieties from low-elevation areas in northern India, the plant is subjected to large variations in conditions - temperatures are >40°C in summer and < 0°C in winter. Days are long in summer and very short (<11 hrs) in winter. These varieties are insensitive to temperature but sensitive to photoperiod. This group can be grown in areas where there is large variation in temperature, and will flower when daylength is short.

Within each duration group we were able to determine variation in response of different genotypes to temperature and photoperiod. While evaluating for adaptation, we were also simultaneously selecting for high grain yield and bold cream-colored seeds. Improved, high-yielding varieties of known adaptation and with farmer- and market-acceptable traits have been selected, constituted into nurseries, and targeted where they are most likely to do well. This approach reduced the workload of national programs. As a result, within the short span of only 6 years, a number of improved varieties have been identified by NARES; some have been released, while others are being tested on-farm (Table 3).

Screening for Disease Resistance

The major pigeonpea disease in the region is fusarium wilt *(Fusarium udum* Butler), while cercospora leaf spot *(Cercospora cajani* Hennings) can also cause serious damage (Reddy et al. 1990). The project used the protocol developed at ICRISAT-Patancheru (Nene et al. 1981) to screen for wilt resistance. A set of germplasm, improved varieties, accessions from different parts of the world, and resistant and susceptible controls were evaluated in wilt-sick plots at Kiboko and Katumani in Kenya. Wilt-resistant varieties with acceptable characteristics were constituted into regional nurseries for further evaluation by NARS. Resistant lines identified in Kenya were evaluated further in wilt-sick plots developed in Malawi and Tanzania. Four long-duration (ICP 9145, ICEAP 00020,00040, and 00053) and five medium-duration (ICEAP 00540, 00550, 00555, 00556 and 00557) wilt-resistant varieties identified using this screening method are now in on-farm trials in Kenya, Malawi, Mozambique, and Tanzania. A breeding program has been initiated to develop high-yielding,wilt-resistant lines.

Integrated Pest Management

Surveys conducted in Kenya, Malawi, Tanzania, and Uganda have provided valuable information on pigeonpea pest populations. Pod borers, podfly, and pod-sucking bugs were identified as important constraints, causing yield losses varying from 17 to 27%. Silim-Nahdy et al. (1999) reported that pod hairiness reduced infestation by bruchids. Other reports suggested that pods borne singularly, as opposed to those in clusters, suffered low damage from pod borers. It had also been suggested that hard pods reduced infestation by insect pests.

Table 3. Varieties selected by national programs for on-farm testing or release.

	Short duration	Medium duration	Long duration
On-farm testing			
Kenya		ICP 6927 ICP 12734 ICEAP 00068	ICEAP 00020 ICEAP 00040 ICEAP 00053
Malawi	ICPL 87091 ICPL 87105 ICPL 87109 ICPL 86005	QP 38 Royes	ICEAP 00020 ICEAP 00040 ICEAP 00053
Mozambique	ICPL 87091		ICEAP 00020 ICEAP 00040 ICEAP 00053
Sudan	ICPL 87091 ICPL 87109 ICPL 90028 ICPL 86005		
Tanzania	ICPL 86005		ICEAP 00020 ICEAP 00040 ICEAP 00053 ICP 9145
Uganda		ICP 6927 ICEAP 0068	
Released varieties			
Kenya	ICPL 87091 Kat 60/8		
Malawi			ICP 9145 ICEAP 00040
Uganda	ICPL 87091 Kat 60/8		
Tanzania	ICPL 87091		

Research has started on screening germplasm for resistance to insect pests and in determining the mechanisms of resistance. Eventually, these components will be combined into an integrated pest management strategy.

Breeding Varieties for Different End-User Needs

We now know the influence of temperature and photoperiod on performance of different duration groups, and also the extent of genotypic variation within each duration group. Although it is now known that the phenology of extra-short and short-duration varieties is delayed by cool temperatures, there are no varieties that mature sufficiently quickly in cool environments - yet these are high potential areas where pigeonpea can give very high yields. In cool environments where long-duration pigeonpea is intercropped with maize, pigeonpea yields are reduced because phenology is accelerated and plants do not recover fully from competition with maize. There is need to develop long-duration varieties with slower phenology that would mature later than maize, thus reducing competition and increasing pigeonpea yield. There are few improved varieties with resistance to diseases; and if there were to be a major disease problem, we may lose them. In addition, the region currently does not have farmer and market acceptable extra-short or short-duration varieties with resistance to fusarium wilt.

Building on the knowledge gained, a breeding program is underway with the following objectives:

- For short-duration varieties, maintaining key traits (relative insensitivity to photoperiod, early flowering and maturity) and incorporating the ability to grow and mature early at low temperature. This would permit farmers to grow pigeonpea at high elevation and latitude.
- For medium-duration varieties, maintaining optimum temperature for time to flower at about 24°C, and incorporating relative insensitivity to photoperiod. This will ensure that if the crop is grown in areas away from the equator but within latitude 20°N or S, flowering is not delayed by long days during summer.
- For long-duration varieties being developed, the objective is to incorporate delay in maturity at low temperature. This will allow farmers in high elevation areas to intercrop maize with long-duration pigeonpea, such that maize matures earlier than pigeonpea, thus reducing competition between the two crops.
- For long-duration varieties, widen the genetic base by incorporating wilt resistance into high-yielding but susceptible varieties.

Objectives one to three (above) involved making crosses between the best short-duration variety ICPL 87091 and the best long-duration varieties (ICP 13076, ICEAP 00020, ICEAP 00040) that have resistance to fusarium wilt. The long-duration varieties are of African origin while the short-duration variety is of Indian origin. The progenies in different duration groups are being tested at two locations in Kenya; Kiboko (warm, 980 m altitude) and Kabete (cool, 1825 m altitude) and the results are extremely exciting:

- For short-duration types, which are now in F_5 the Project has identified progenies which are insensitive to cool temperature and Whose phenology is not delayed in cool environments. In addition, seed mass has been increased substantially.
- For long-duration types, which are in F_5, yields are substantially higher than the parents, and seed mass has not been reduced. In addition, progenies have been identified that mature later than the long-duration parents in cool environments (Table 4).
- Progenies with tolerance to fusarium wilt have been identified in all duration groups.

Table 4. Performance of long-duration genotypes under development (f_5 generation) at Kabete, Kenya, 1998/99 cropping season.

Genotype	Days to 50% flower	Days to 75% maturity	Plant height at maturity (cm)	100-seed mass(g)	Grain yield (t ha^{-1})
IAPX 95001-18-2-13-F5B	120	177	172	24.3	6.72
IAPX 95001-19-3-10-F5B	111	172	164	20.5	6.29
IAPX 95002-7-18-10-FB5	114	172	156	19.0	5.51
IAPX 95001-16-2-11-F5B	114	172	192	19.5	5.22
IAPX 95001-13-7-14-F5B	119	177	160	21.8	5.00
IAPX 95001-11-20-19-F5B	119	177	173	21.4	5.16
IAPX 95001-21-14-7-F5B	115	172	205	20.1	5.13
IAPX 95001-17-8-21-F5B	120	178	138	22.4	'4.43
IAPX 95001-16-13-10-F5B	102	167	163	19.3	4.18
IAPX 95002-9-32-18-F5B	113	172	159	22.7	3.99
IAPX 95002-8-12-8-F5B	113	172	137	20.9	3.89
IAPX 95002-11-14-9-F5B	112	170	142	19.3	3.26
IAPX 95001-6-16-15-F5B	113	172	125	17.6	2.94
IAPX 95001-18-2-14-F5B	112	170	158	18.3	2.86
IAPX 95001-14-7-10-F5B	101	167	128	19.3	2.61
ICEAP 00053	114	170	141	19.6	2.46
IAPX 95001-17-8-25-F5B 115	112	170	113	19.4	2.43
IAPX 95001-21-25-10-F5B	113	170	165	17.7	2.41
ICEAP 00020	114	170	156	20.2	2.29
ICEAP 00040	111	170	126	19.9	2.28
Grand Mean	113	172	154	20.1	3.96
SE±	0.9	1.1	9.6	0.9	0.79
CV(%)	1.1	0.9	8.8	6.5	27.8

f_5 generation; crosses made between short-duration ICPL 87091 and long-duration varieties (ICEAP 00020, ICEAP 00040, ICP 13076)

Priorities for the Future

Pigeonpea will continue to be grown by farmers who are resource-constrained; and both green peas and dry grain will remain important. Eastern Africa is a secondary center of diversity, where the crop has distinct characteristics and specific adaptation. A breeding strategy specifically for the region is therefore necessary.

Dual purpose extra-short and short-duration varieties

Efforts will need to target farmers with relatively better resources and more endowed environments, with varieties aiming at the green pea and dry grain markets. Without pest resistance, judicious use of pesticides will continue to be the only way to control pests. Incorporation of insensitivity to cool temperatures will allow the expansion of this duration group into high-elevation areas near the equator and high-latitude areas where pigeonpea currently cannot be grown due to cool temperatures during the reproductive stage. It is envisaged that with intensification of production, fusarium wilt will become a major constraint - and control should therefore be an important priority. Use of molecular biology approaches to alleviate biotic and abiotic constraints should also be explored, particularly for control of pests. This will involve collaboration with advanced research institutions.

Medium-duration varieties

Medium-duration varieties are mostly intercropped, and grown in areas with warm temperatures unsuitable for long-duration varieties. Near the equator, efforts should focus on developing varieties with good ratoonability so that farmers can obtain two crops a year. The major beneficiaries will be Kenya, Uganda, and Tanzania. In currently available medium-duration varieties, phenology is delayed in areas away from the equator, e.g. Malawi and Mozambique. Thus, we are unable to extend production into non-traditional areas where long-duration varieties fail due to terminal drought. It is important to incorporate insensitivity to photoperiod in medium-duration types. The major beneficiaries will be southern Tanzania, middle Malawi (Lilongwe plateau), northern Mozambique, Sudan, Ethiopia, and Eritrea. Wilt resistance and tolerance to insect pests should also be incorporated, using biotechnological tools where conventional approaches are unsuccessful.

Long-duration varieties

These varieties are mostly intercropped, and grown in low-latitude, high-elevation areas (near the equator, >900 m) and in areas slightly away from the equator (within 17°N and S) where temperatures are warm during the vegetative stage and cool during the reproductive stage. Efforts should be continued in developing improved varieties incorporating high yield, acceptable grain characteristics, resistance to diseases, mainly fusarium wilt, and tolerance to insect pests. Where a conventional approach is not possible, biotechnological tools should be used. For areas near the equator with elevation >1400 m, and where maize is the main crop, research should aim to incorporate insensitivity to cool temperature to allow the crop to mature later and thus reduce competition between maize and pigeonpea.

Vegetable pigeonpea

There is a growing niche market for green (vegetable) pigeonpea. No varieties have been specifically bred for this market, but dual-purpose varieties have been found to be acceptable. We are still in the process of getting information on market needs, traits associated with quality, shelf life etc, which will be used to develop varieties specifically for vegetable pigeonpea.

Hybrid pigeonpea

As the crop becomes more commercialized, yield, market traits, and seed issues will become increasingly important. Private seed companies will become interested in pigeonpea only if there is the potential for developing hybrids. The technology is available in ICRISAT-Patancheru and should be transferred to the region.

Protecting biodiversity and collections

Given the present low number of *ex situ* collections from the region, it is highly probable that traditional germplasm from the region will be lost if farmers were to shift (even in the short term) to new crops or varieties. The extent of genetic erosion is not known and the uniqueness of the material has not been determined. As we develop new varieties, we need to ensure that local germplasm is preserved through collections, characterization, and preservation in regional genebanks, and through agreements a duplicate sample deposited with ICRISAT.

Teamwork

ICRISAT believes research should be demand driven and that each research partner should bring in a comparative advantage. A careful analysis as the starting point of a collaborative project generates confidence among partners as well as development investors. This process requires the participation of NARS, civil society, private sectors, NGOs, advanced research institutes, and farmers, to ensure that the work remains relevant and on track.

References

Ali, M. 1990. Pigeonpea cropping systems. Pages 279-301 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds). Wallingford, UK: CAB International.

Byth, D.E., Wallis, E.S., and Saxena, K.B. 1981. Adaptation and breeding strategies for pigeonpea. Pages 259-270 *in* Vol. 1, Proceedings of the International Workshop on Pigeonpea, 15-19 Dec 1980, Hyderabad. Patancheru 502 324, Andhra Pradesh, India: ICRIS AT.

Nene, Y.L. 1991. Pigeonpea research: future strategies in Africa. Pages 1-4 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Nene, Y.L. and Sheila, V.K. 1990. Pigeonpea geography and importance. Pages 1-14 301 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds). Wallingford, UK: CAB International.

Nene, Y.L., Kannaiyan J., and Reddy, M.V. 1981. Pigeonpea diseases: resistance screening techniques. Information Bulletin no. 9. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Omanga, P.A, Summerfield R.J., and Qi, A. 1995. Flowering of pigeonpea (*Cajanus cajan*) in Kenya: responses of early-maturing genotypes to location and date of sowing. Field Crops Research 41:25-34.

Reddy, M.V., Sharma, S.B., and Nene, Y.L. 1990. Pigeonpea diseases and management. Pages 303-346 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds). Wallingford, UK: CAB International.

Silim Nahdy, M., Silim, S.N., and Ellis, R.H. 1999. Some aspects of pod characteristics predisposing pigeonpea (*Cajanus cajan* (L.) Millsp) to infestation by *Callosobruchus chinensis* (L.). Journal of Stored Products Research 35:47-55.

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 (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Singh, L., Gupta, S.C., and Faris, D.G. 1990. Breeding. Pages 375-400 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds). Wallingford, UK: CAB International.

Summerfield, R.J., Lawn, R.J., Roberts, E.H., and Ellis, R.H. 1991. Towards the reliable prediction of time to flowering in six annual crops. 1. The development of simple models for fluctuating field environments. Experimental Agriculture 27:11-31.

Summerfield, R J., Lawn, R.J., Qi, A., Ellis, R.H., Roberts, E.H., Chay, P.M., Brouwer, J.B., Rose, J.L., Shanmugasundaram, S., Yeates, S.J., and Sandover, S. 1993. Towards the relaible prediction of time to flowering in six annual crops. II. Soyabean (*Glycine max*). Experimental Agriculture 29:253-289.

Whiteman, E.S., Byth, D.E., and Wallis, E.S. 1985. Pigeonpea [*Cajanus cajan* (L.) Millsp]. Pages 658-698 *in* Grain legume crops (Summerfield, R.J. and Ellis, R.H., eds). London, UK: Collins.

Pigeonpea Breeding: Objectives, Experiences, and Strategies for Eastern Africa

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Introduction

Pigeonpea is probably the most important grain legume in the semi-arid areas of Eastern Africa. Reports indicate that it is grown in 37 African countries at altitudes ranging from sea level to 2050 m. The leading producers in Africa are Kenya (164,000 ha), Uganda (113,000 ha), Malawi (110,000 ha), Tanzania (33,000 ha) and Mozambique. Pigeonpea is mainly produced by smallholder farmers in mixtures with maize, sorghum, cotton, finger millet, and other legumes such as beans. In most parts of Africa, pigeonpea is grown as a multi-purpose grain legume; eaten as grain or as a vegetable.

Yield-Limiting Factors and Breeding Objectives

Grain yield on farmers' fields in Eastern Afria average 450-670 kg ha^1, compared to 2.6-4.3 t ha^{-1} reported from research trials in Kenya (Onim and Ruhaihayo 1975, Onim 1984). A number of biotic and abiotic constraints contribute to this gap between potential and actual yields. Correspondingly, the major objectives of pigeonpea breeding programs in the region include:

- Grain yield
- Early maturity and reduced height
- Resistance to diseases, especially fusarium wilt
- Resistance to insect pests, especially pod borers, pod suckers, and podfly
- Seed characteristics, especially size and color
- Tolerance to drought
- Suitability for intercropping
- Enhanced nitrogen fixing potential and survival in infertile soils
- Special-purpose varieties for agroforestry and forage types
- Adaptation to different ecological zones.

Yield potential Until the early 1980s no improved varieties were available to farmers in the region. Although several improved varieties are now available, adoption is limited and most farmers grow low-yielding, late-maturing landraces. Yields of up to 4.6 t ha^1 have been reported in on-farm trials of new varieties, indicating that productivity can be substantially improved with new varieties and better crop management.

Early maturity. Late-maturing varieties (typically 8-11 months) leave farmers with little time to prepare the field for the next crop. To avoid such delays farmers often plant widely

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spaced rows of pigeonpea, and sow other fast-maturing crops in between (wide row spacing also facilitates land preparation and weeding). The long duration may be a disadvantage for subsistence farmers who have to wait nearly a year to harvest. Varieties with different maturity durations should be developed to fit different cropping systems and agro-ecological zones, but early-maturing cultivars should be given priority.

Plant height. Most local varieties are tall (over 2 m), and are thus difficult to harvest and spray. They cannot be grown in close association with shorter plants due to shading effects unless wide spacing is used or by exploiting their slow early growth. They also tend to lodge - therefore short or medium-statured varieties may be more desirable.

Diseases. Several pigeonpea diseases have been reported in Eastern Africa. Fusarium wilt is by far the most important: Kannaiyan et al. (1984) reported incidence of 5-60% in Kenya and 36.3% in Malawi (range 0-90%). Leafspot caused by *Mycovellosiella cajani* causes severe defoliation and yield losses of up to 80% especially during wet years (Onim 1981). It has been reported as a serious problem in Kenya, Zambia, and Uganda. Chemical control is often not viable for subsistence farmers; the best option is probably the development of resistant varieties.

Insect pests. Pigeonpea is attacked by a number of insect pests. Pod borers (*H. armigera, M. vitrata),* pod suckers (C. *tomentosicollis*), and the podfly *M. chalcosoma* are the most serious, causing losses of 26-63%. Most farmers do not spray their crops due to the high cost of insecticides. Consequently, yield losses will depend on infestation levels and the natural tolerance of the plant. Efforts to develop pest-resistant varieties have met with little success; and there is still limited understanding of insect-host relationships and control methods. There is an urgent need to develop pigeonpea varieties tolerant of both field and storage pests as a component of integrated pest management strategies.

Seed and pod characteristics. Consumers and producers in the region prefer large, white/ cream seeds and large pods (5-7 seeds/pod). Much of the local germplasm is large-seeded, with 100-seed mass >15 g, and can be used to developed improved cultivars with the necessary characteristics.

Drought stress. Pigeonpea is grown mainly in semi-arid areas with unreliable rainfall, where crop failures are frequent. Although pigeonpea is drought tolerant, it grows best with rainfall of 600-1000 mm. Yields are substantially reduced under drought. This can be overcome by developing either early-maturing varieties or varieties with tolerance to drought.

Soil fertility. Although pigeonpea grows on a wide range of soil types it gives optimum results in deep loam, almost neutral soils of pH range 5-7. Soils outside this range or those lacking nutrients will not produce good yields. Most smallholders do not apply fertilizer on pigeonpea; and animal manure is not used in adequate quantities. Pigeonpea also suffers because of badly drained soils.

Crop management. Late planting, inadequate weeding, poor land preparation, and low plant populations contribute to the low yields. Future efforts in Eastern Africa must concentrate on disseminating the improved technologies already available.

Agroforestry and soil conservation. Pigeonpea is a multipurpose woody legume with great potential in agroforestry. The plant supplies not only food, but also forage and wood for fuel, fencing and construction materials. The deep root system also helps in stabilizing soil conservation terraces.

Adaptability. Pigeonpea is successfully grown in a range of environments, but each maturity group has its specific area of adaptation. Phenology is affected considerably by temperature (altitude) and daylength (latitude), and varieties could fail to flower or yield if grown outside their areas of adaptation. It is therefore important to test new varieties over as wide an area as possible to determine the areas of optimum productivity. It would also be useful to define and characterize pigeonpea-growing environments in the region so that breeders can target cultivars to specific environments.

Socio-economic factors. Pricing, marketing, and infrastructure indirectly determine how much effort and investment farmers will make in pigeonpea production. There are no organized marketing systems for pigeonpea; export markets have not been exploited fully, and price incentives are limited. Poor roads, poor seed delivery systems, and lack of storage and transport facilities make it difficult for farmers to intensify production. Labor shortages are severe, because most children and young adults, who traditionally provided family labor, have migrated to urban areas.

Development of Pigeonpea Breeding Programs

The earliest pigeonpea program in Eastern Africa was initiated in Uganda in 1968. Two programs were later started in Kenya in 1975 and 1980; and subsequently in other countries in the region.

Breeding methods in Eastern Africa

Most national pigeonpea breeding programs in Eastern Africa are in their early stages. These programs have generally followed a similar pattern from introduction, through mass selection to hybridization and selection, with a corresponding degree of complexity and demand for skills and resources.

Introduction. Virtually all programs started by introducing cultivars and advanced breeding lines from ICRISAT-India and other diverse sources. In many cases, the materials introduced between 1970 and 1990 failed to meet farmers' requirements (large cream or white seeds); and adoption was poor. In the early 1990s, ICRISAT provided white-seeded lines, some of which were released in the late 1990s.

Mass selection. In a few cases, the introduced early-maturing germplasm was grown together with local long-duration landraces. This generated segregating populations with variable maturity duration (Shakoor et al. 1983). The medium-duration Kat 60/8, which is now grown by farmers in Kenya and Uganda, was selected from such a population. Local landraces were also collected and selections made either through simple mass selection or mass selection with progeny testing (Onim 1981). Germplasm collection missions were concentrated in Kenya, Tanzania, and Malawi. Selections from landraces were evaluated both on-station and on-farm. Long-duration cultivars such as Munaa and Kioko (released in Kenya) and ICP 9145 (released in Malawi) are selections from local landraces. Others such as

ICEAP 00068 and ICEAP 00040, both selected from landraces, have been recommended for release.

Hybridization and selection

Only a few national programs (Kenya, Malawi) have been successful in combining useful traits from the diverse germplasm into new cultivars. Introduction and mass selection limits the breeder to identification of the best genotype in the breeding collection. Most national programs have no organized breeding scheme with provision for creating segregating populations from which useful recombinants can be selected. Development of well-designed breeding programs will be a major challenge for African pigeonpea breeders in this millennium.

Another challenge is the high degree of outcrossing in pigeonpea; as a result breeding procedures differ from those used for predominantly self-pollinated crops (Kimani 1987). Outcrossing also poses serious problems in the maintenance of pure lines under open-pollinated conditions. Controlled production of self-pollinated seed by bagging, while necessary for maintaining purity, is costly, time-consuming, and produces only limited amounts of seed. This method is not economical for large-scale seed production.

Review of Breeding Programs in the Region

The following section reviews the more important pigeonpea breeding programs in the region.

Makerere program, Uganda

The first pigeonpea program in the region was initiated in 1968 at Makerere University, Uganda, to breed short-duration, high-yielding cultivars of the dry grain type. Since most of Uganda has two distinct growing seasons, short-duration cultivars would enable farmers to plant two pigeonpea crops in a year, or alternatively fit it into rotations in a double cropping system (Khan and Rachie 1972).

Germplasm was collected from India, the Caribbean, the Philippines, and other sources. The collection of about 5400 accessions was evaluated, and 500 selected for breeding work. Breeding methods at Makerere emphasized introduction, selection, and to a lesser extent hybridization. Single-plant selections from the germplasm and from segregating populations were evaluated; and reasonably uniform elite lines were bulked and entered in yield trials during 1969 and 1970.

A number of high-yielding lines were identified, representing two plant types: "spray" and "bush" types. "Spray" types had secondary branches almost as long as the main stem, with very little tertiary branching (i.e. spreading types). The erect bush type was recommended for reduced row spacing (80 cm), which increased plant populations and hence gave higher yields. The new lines gave yields substantially higher than the national average (Dunbar 1969). Most of these promising lines were of Indian parental stock but their yields in Uganda were modest compared to the high yields reported in India.

Population improvement Makerere started a population breeding program that was believed to be more appropriate due to the high outcrossing, easier to conduct, and offered consistent improvements in future (Khan 1973). The natural populations in Uganda had a rather restricted base. Two populations were therefore formed, an Early Composite and a Medium Composite.

The Ugandan program was disrupted by civil strife between 1973 and 1986. Some of the materials were used to initiate the breeding program at the University of Nairobi in 1975.

Nairobi and Katumani programs, Kenya

Pigeonpea improvement work was initiated at the Department of Crop Science, University of Nairobi, in 1975 and the National Dryland Farming Research Centre, Katumani, in 1979. The early stages of the program focused on germplasm collection and evaluation, followed by selection and later on hybridization and selection.

Germplasm collection. Collections have been made in virtually all provinces of Kenya. Between 1975 and 1977,607 accessions were collected by the University of Nairobi through local collections, and from Makerere, ICRISAT-India, IITA-Nigeria, University of West Indies, Trinidad, and Sudan. This germplasm showed tremendous variability for various agronomic characters and one entry was completely male sterile. More accessions were added in 1997 and the collection now has about 1000 accessions.

Selection from local landraces. Germplasm collected in farmers' fields was evaluated in 1977 and several single plants were selected and selfed. In on-farm tests, local and improved cultivars (single plant selections) performed similarly in most characteristics except grain yield, where the selections yielded 94% more than local cultivars.

Population improvement. This approach was used because of the high degree of outcrossing. Onim (1981) compared two population improvement methods, namely stratified mass selection (SMS) and mass selection with progeny testing (MSPT). These methods were evaluated on an early-maturing composite population between 1975 and 1978. The composites, originating from the Makerere University program, were evaluated after two to four cycles of selection for grain yield and drought tolerance. In a wet season, the unimproved population yielded as well as the SMS-C4 and MSPT-C2 improved populations; but the improved populations were superior in a dry season. Both population methods were successful in improving grain yield under marginal rainfall conditions. Progress per cycle was 2.3% for SMS populations after four cycles of selection, compared to 4.3% under MSPT. The slightly better response in MSPT was attributed to progeny testing and a higher selection pressure of 5% versus 10% in SMS. The SMS method was just as good as MSPT, takes a shorter time per cycle, and is easier to operate.

Development of early-maturing cultivars. Until the early 1980s, no early-maturing pigeonpea cultivars were available to farmers in Kenya. Earlier attempts to popularize early-maturing cultivars from India failed because farmers rejected the varieties - despite their early maturity and short stature - due to seed size and color. Also, the Indian cultivars were not suitable for intercropping, losing up to 80% of their grain yield when intercropped with maize (Onim 1981).

The first early-maturing cultivar developed in Kenya was NPP 670, which originated from crosses made in 1977 between early-maturing lines from ICRISAT and locally adapted landraces. It has been adopted in parts of Mbeere, Machakos, Embu, and Kitui districts, where it is popularly known as 'Katumani' pigeonpea. It is popular primarily because of its early maturity and large cream seeds (19 g per 100 seeds). NPP 670 yields about 1 t ha^{1} on farmers' fields, but is highly susceptible to insect pests - spraying is essential.

Since farmers value other traits in addition to earliness, attempts were made in 1983/84 to combine seed traits from local material with earliness from Indian genotypes through controlled crossing in the glasshouse, and in a nursery established at Kiboko. The segregating populations were advanced to F_7 through bulk breeding procedures, promising lines tested for wilt tolerance, and yield trials conducted at several locations. The selected lines were shorter and matured much earlier than the local long-duration improved and traditional varieties. They are large seeded (>13.5 g per 100 seeds), but seed mass is lower than that of check cultivars. All the lines are tolerant to wilt; three lines showed a high degree of resistance. They were similar to NPP 670 in maturity duration and pod size, and gave higher yields.

Tanzania

Pigeonpea research in Tanzania started in the early 1960s, when varieties collected from Ukiriguru (Tanzania) were grown in observation plots at the Agricultural Research Institute (ARI), Ilonga in 1962/63 to screen for wilt resistance. This work was discontinued following the departure of scientists involved in crop research, but resumed in 1974/75 when the National Grain Legumes Research Program (GLRP) was started at ARI-Ilonga. Sixty lines, including six dwarf, short-duration genotypes from ICRISAT, were evaluated that season. These lines formed few or no branches, fruited profusely on the main stem, and the best lines gave grain yields of up to 2 t ha^{-1} (Laxman Singh 1990).

The next phase began in 1986/87 when a Pigeonpea Germplasm International Trial was conducted jointly with ICRISAT scientists at ARI-Ilonga, Gairo (Kilosa district), and the Sokoine University of Agriculture. The most promising lines flowered in 55-60 days and matured in 110-115 days. Although the data are limited, it appears that early-maturing pigeonpea has potential under Tanzanian conditions.

Ethiopia

Pigeonpea research in Ethiopia was started early in the 1970s by the Institute of Agricultural Research (IAR) at Nazret National Horticultural Centre, with short-duration cultivars introduced from Makerere University, the Dominican Republic and later from Guyana, IITA, and ICRISAT-India (Amare Belay, pers comm). The main objective was to identify high-yielding, disease and pest tolerant cultivars. During 1973-77 the introductions were tested in nurseries, variety trials, and national yield trials at Nazret, Arelkasa, Adam, and Koko in Central Ethiopia by the Welayta Agricultural Development Unit (WADU) in southern Ethiopia, Kobo in northern Ethiopia, and Humera in northwestern Ethiopia. Yields were inconsistent in different years at most locations except at WADU and to some extent at Melkasa.

Further evaluations of local and exotic collections from the Genetic Resources Unit of Ethiopia, International Livestock Centre for Africa (ILCA), and ICRISAT were conducted between 1986 and 1990. Most of these cultivars have yet to reach many farmers due to inadequate extension and seed production and distribution systems. Little information is available on the status of traditional Ethiopian varieties, local preferences for seed size and color, and farmers' reactions to the new short-duration cultivars.

Rwanda

Pigeonpea research in Rwanda began in 1983 with the introduction of early-maturity seeds from the cross NPP 610, originally made at the University of Nairobi (Price and Cishahayo 1986). About 75 seeds from this cross as well as seeds of other Kenyan landraces, were supplied by the International Development Research Centre (IDRC), Nairobi. In the same year, several Tanzanian landraces were obtained from the Tanzania Agricultural Research Organization at Ilonga. Several distinct phenotypes were isolated from the cross NPP 610. Material with desirable characters - early maturity, large seeds, reduced plant height, drought tolerance, high yield potential, adaptability to poor soils - were selected and tagged from the segregating NPP 610 and Tanzania selections. Three individual plants selected from NPP 610 were crossed in all combinations. Intrapopulation recurrent selection aimed at improving grain yield and adaptability was employed for three cycles on the segregating populations. Variability after cycle 3 was maintained by the very high natural outcrossing. The population RK101 (short, early maturing) was derived by this method.

Selections from medium-duration types from Tanzania were crossed to produce the population RT 201 which was medium in height, early to medium duration, large-seeded, and adapted to the region. RKT 120, a tall, large-seeded, long-duration perennial type, is derived from single plant selections within a population of landraces received from Kenya. The improved varieties have larger seeds and more seeds per pod than the local varieties (Price and Cishahayo 1986), but the impact of these varieties is yet to be determined.

Sudan

Studies on crop improvement and agronomy were started at Hudeiba Research Station during 1975-80, supported by IDRC (Nourai 1987). The main objectives of the program were to select high-yielding, adapted pigeonpea varieties, and to obtain information on maturity, plant type, and seed size and color. Forty early, medium, and late-maturing entries from ICRISAT were compared to the standard local variety Baladi for three seasons. Three introduced varieties outyielded Baladi by over 100%.

Somalia

The status of grain legume research in Somalia was reviewed by Abikar (1990, unpublished). The Somali diet consists of cereals and tubers which are rich in starch and low in protein. Although pulse crops have potential and production fails to meet demand, little research has been conducted on pulses. Recently the Central Agricultural Research Station at Afgoi and

Bonka developed a program for grain legume production including pigeonpea. However, little progress has been made due to the political instability in Somalia since 1991. The fate of improved lines sent to Somalia in 1988 is not known.

Burundi

No genetic improvement work on pigeonpea has been done in Burundi (Ntukamazina and Nzimenya 1987). Most varieties grown by farmers were introduced (source unknown), with Burundi farmers adopting them where they proved adaptable. Farmers distinguish two maturity groups: long and short duration.

Future Prospects and Strategies for Pigeonpea Breeding

Pigeonpea improvement programs in Eastern and Southern Africa have relied heavily on advanced lines and varieties from ICRISAT and other breeding programs in the region, and also made selections from their own landraces. Although varieties released from these materials have served the immediate need of farmers, major deficiencies still exist. There is need to develop cultivars that combine several novel traits to better meet the changing needs of pigeonpea growers and consumers. It is unlikely that cultivars combining multiple desirable traits will be found from existing germplasm collections. The challenge for breeders will be to examine a wide range of genotypes and construct new varieties meeting criteria for each agro-ecological zone and addressing consumer needs. New strategies will have to be developed and implemented in partnership with other stakeholders. Some potential strategies are suggested below.

Breeding for variable maturity duration

Because most of the landraces grown by farmers are late-maturing, new short- and medium-duration cultivars have received wide acceptability. A few such varieties have been developed, e.g. short-duration ICPL 87091, but the number of such examples is limited. Varieties in the early-medium and medium-duration groups include NPP 670, Kat 60/8, ICEAP 00068, and ICP 6927. The early-maturing cultivars were developed for purestand cropping while the medium-duration types were intended primarily for intercrop systems, and late-maturing improved cultivars such as ICEAP 00040 and ICEAP 00020 were intended for two-season intercrop systems. Future research will need to focus on correcting deficiencies in these cultivars. For example, ICPL 87091, NPP 670, Kat 60/8, ICEAP 00068, ICP 6927, and ICEAP 00020 are susceptible to fusarium wilt. Determinate cultivars such as ICPL 87091 and NPP 670 are very susceptible to insect pests. Seed size of ICPL 87091 and Kat 60/8 requires further improvement, from 11-12 g to over 15 g per 100 seeds.

Multiple constraint breeding

Pigeonpea growers face a number of biotic and abiotic constraints often acting in combination. Diseases, pests, and adverse climatic and soil conditions can be present in the same field at the same time. It is not uncommon to find more than one disease on the same plant during one or more developmental stages. Such multiple constraints reduce yield and quality and increase instability of production. This also increases the cost of control measures. Thus, the need for multiple-stress resistance is particularly relevant in pigeonpea, which is grown largely by smallholder farmers who can rarely afford costly inputs (fungicides, insecticides, fertilizers etc) for a low-priced crop such as pigeonpea.

Attempts to accumulate in one line, resistances to various stresses date back many years. But until recently this approach was used only to a limited extent, partly because of lack of suitable resistance sources, screening procedures, and proven breeding methods to simultaneously handle multiple traits. As a result most breeding programs have used a stepwise procedure to solve the different problems one by one, starting with the problem which is most yield limiting. Among the weaknesses of this approach is the lengthy period required to incorporate resistance to several stresses. In addition, "resistant" cultivars tend to be resistant to one stress but susceptible to others. Although this approach is still in use, there is increased interest in breeding programs attempting to simultaneously introduce genes for multiple resistances. Selecting for multiple traits becomes more difficult with an increasing number of traits to be improved. National programmes and their partners need to develop suitable breeding schemes for multiple constraint improvement of pigeonpea.

Marker-assisted selection

Plant breeders are increasingly using DNA markers to increase the efficiency of recovering genes for desirable traits. Target genes in a segregating population can be identified and selected using marker-assisted selection (MAS). However, use of MAS requires detailed information on the pigeonpea genome and mapping of agriculturally important "target" genes. In contrast to conventional direct selection, MAS selects individuals carrying target genes in a segregating population based on patterns of tightly linked markers rather than on their phenotypes (Zheng et al. 1995). Therefore, the population can be screened at any growth stage and in various environments. Screening for resistance to a disease can be done without artificial inoculations if markers for that resistance gene(s) are available. In addition, MAS can eliminate interference from intra-locus or inter-locus interactions and thus increase the efficiency and accuracy of selection, especially for traits that are difficult to assess. However, MAS will not be available to pigeonpea breeders until saturated genetic maps and suitable DNA markers have been developed. In addition simple, rapid, accurate, cost-effective procedures must be established which are complementary to existing breeding protocols.

Inter-genepool crosses

Although pigeonpea is now believed to have originated from the Indian subcontinent, it has been grown and selected in East Africa for many thousand years and the area is regarded as the chief secondary center of domestication and diversity (Remanandan et al 1982). The result of this long period of domestication and selection are landraces with unique features such as long duration, perennial habit, large leaflets, high number of seeds per pod, large cream or speckled or mottled seeds, which contrast sharply with materials originating from the Indian subcontinent. For example the world collection at ICRISAT contains two landraces with the highest known 100-seed mass, collected from Kenya (26.92 g) and Tanzania (26.47 g). Similarly, 3-5 seeds/pod is usual in Asian genotypes, while East African landraces average 5-7 seeds/pod. It is likely that even more significant differences can be detected at the molecular level or by analysis of biochemical composition. These evolutionary differences suggest that there may be at least two major genepools in pigeonpea - African and Asian. The complementary characters of these genepools have been used only to a limited extent. Future breeding activities will need to generate more variability from inter-genepool crosses.

Hybrid pigeonpea

The first hybrid pigeonpea cultivar was developed by ICRISAT and released for cultivation in India in 1990. The hybrid had a 20-40% yield advantage over open-pollinated varieties. Production was facilitated by the discovery of male sterility and inbred lines developed in India. This technology was subsequently taken up and commercialized by several seed companies. Since hybrid vigor is generally associated with genetic diversity, crosses between the genetically diverse African and Asian genepools may have considerable heterosis. To our knowledge, this opportunity has not been explored. We propose that national programs including universities and their partners should devote at least part of their efforts in this direction.

Conclusions

National agricultural research institutes and universities in Eastern, Central and Southern Africa in collaboration with ICRISAT, Institut de Agronomiques of Gembloux, and the University of Bonn have made considerable progress in developing improved pigeonpea cultivars and management practices in the last two decades. New early and medium-duration varieties are now being grown in semi-arid regions. However, widespread dissemination is seriously hampered by inadequate seed delivery systems. Although the improved cultivars have helped increase productivity, they have important deficiencies that are likely to reduce their yield potential in some environments and their appeal to consumers and producers. The deficiencies include small seed size and susceptibility to wilt, cercospora leafspot, and insect pests. So far, national breeding programs have relied on nearly finished lines from ICRISAT and selections from their landraces - few have developed their own crossing programs. Future activities should therefore include a capacity building component for NARS. The next generation of varieties is likely to originate from well designed breeding schemes, which should be based on creating recombinant populations from intra- and inter-genepool crosses with the aim of redressing limitations of the current varieties. Various strategies (multiple constraint breeding, marker-assisted selection, TCM, hybrid development from inter-genepool crosses) offer new opportunities to increase efficiency in cultivar development and enhance productivity in pigeonpea.

References

Dunbar, A.R. 1969. Pages 68-70 *in* Annual crops of Uganda. Nairobi, Kampala and Dar es Salaam: East African Literature Bureau.

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

Khan, T.N. 1973. A new approach to breeding of pigeonpea (*Cajanus cajan* (L.) Millsp): formation of composites. Euphytica 22:373-377.

Khan, T.N. and Rachie, K.O. 1972. Preliminary evaluation and utilization of pigeonpea germplasm in Uganda. East African Forestry Journal 38(I):78-82.

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. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Le Roi, A. 1997. Evaluation of the situation of pigeonpea production in semi-arid areas of Kenya. MSc thesis, Gembloux Agricultural University, Gembloux, Belgium. 75 pp.

Nourai, A.H. 1987. Chickpea and pigeonpea production in Sudan. *In* Research on grain legumes in Eastern and Central Africa: summary proceedings of Consultative Group Meeting for Eastern and Central Africa, 8-10 Dec 1986. Addis Ababa, Ethiopia, ILCA; and Patancheru 502 324, Andhra Pradesh, India: ICRIS AT.

Ntukamazina, R. and Nzimenya, I.1987. Groundnut and pigeonpea cultivation in Burundi. *In* Research on grain legumes in Eastern and Central Africa: summary proceedings of Consultative Group Meeting for Eastern and Central Africa, 8-10 Dec 1986. Addis Ababa, Ethiopia, ILCA; and Patancheru 502 324, Andhra Pradesh, India: ICRIS AT.

Onim, J.F.M. 1981. A summary of the Fourth Progress Peport of Pigeonpea Project for IDRC. Nairobi, Kenya: Dept of Crop Science, University of Nairobi. 31 pp.

Onim, J.F.M. 1984. On-farm testing of improved pigeonpea *(Cajanus cajan* (L.) Millsp) cultivars in Kenya. Pages 65-72 *in* Crop improvement in Eastern and Southern Africa: research objectives and on-farm research (Kirkby, R.A., ed). Proceedings of a regional workshop, Nairobi, 20-22 Jul 1983. Ottawa, Canada: IDRC.

Price, M. and Cishahayo, D. 1986. Pigeopea improvement in Rwanda. Paper presented at the workshop on pigeonpea in Eastern Africa, 8-11 Apr 1986, Nairobi. Nairobi, Kenya: University of Nairobi; and Ottowa, Canada: IDRC.

Remanandan, P.A., Shakoor, A., and Ngugi, E.C.K. 1982. Pigeonpea germplasm collection mission in Kenya, Sep-Oct 1982. Patancheru 502 324, Andhra Pradesh, India: Genetic Resources Unit, ICRIS AT. 40 pp.

Rubaihayo, P.R. and Onim, J.F.M. 1975. A study of some characters of pigeonpea. Sabrao Journal 7(2): 183-187.

Singh, Laxman. 1990. 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 (Singh, Laxman, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Shakoor, A., Muthoka, M.S., and Ngugi, E.C. 1983. Development of early maturing pigeonpea in Kenya. International Pigeonpea Newsletter 2:18.

Zhang, K., Huang, N., Bennet, J., and Kush, G.S. 1995. PCR-based marker assisted selection in rice breeding. IRRI Discussion Paper Series No.12. Manila, Philippines: International Rice Research Institute.

New Regional Initiatives in Pigeonpea Improvement

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Introduction

Two major regional initiatives for pigeonpea improvement were started in the last decade, with similar objectives, i.e. to enhance pigeonpea productivity on smallholder farms. One was a collaborative program involving 10 countries in Eastern and Southern Africa, supported by the African Development Bank and coordinated by ICRISAT. This program began in 1991 and was completed in 1999. The second initiative was an inter-university program initiated in 1996, involving Gembloux, Bonn, Makerere, and Nairobi universities supported by the European Union and the Belgian Agency for International Cooperation. The program was implemented in collaboration with ICRISAT and the national research and extension programs in Uganda and Kenya. Papers elsewhere in these proceedings have described progress under the first initiative and the work done by various partners under the second initiative. This paper focuses on work done at the University of Nairobi under the second regional initiative.

Characterization of Regional Germplasm Resources

Much of the germplasm collected in Eastern Africa has been characterized to some degree. It shows wide variability in a range of characters that may be useful in future crop improvement programs. To complement the previous collections, additional germplasm was collected in 1997 from pigeonpea-growing districts around Mount Kenya and the coastal lowlands of Kenya (Kimani et al. 2000). All the new and old accessions conserved at the Department of Crop Science, University of Nairobi, and Gembloux Agricultural University, Belgium, were initially grown in observation nurseries and further characterized in trials at Kibwezi (altitude 900 m), Thika (1600 m), and Kabete (1890 m) over a 3-year period. The main features of these materials are summarized below.

Growth habit. Most are erect, tall, compact to semi-spreading. They vary in height from about 1 to 4 m. Branching is variable but above 1 m on the stem is common. Some show profuse branching (4-28 primary branches) and leaflets are generally large.

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Maturity duration. Most are long-duration, usually 8-11 months, and perennial. Some early-maturing types resulted from outcrosses with exotic early-maturing germplasm.

Stem color. Usually purple or green.

Flowers. There is considerable variability for flower color. Flowers may be yellow to red, ivory and with variable densities of streaks on the standard. Some have no streaks, others show uniform coverage.

Pods. Most landraces show a high number of seeds per pod: 5-7 is common. Landraces from the coastal lowlands have 6-8 seeds/pod. A range of 3 to 9 seeds/pod has been reported. Pods may be green or purple or a mixture of purple and green, and formed in large bunches that are easy to harvest. Pods per plant vary from 15 to over 1000.

Seeds. The landraces have large seeds with an average 100-seed mass of about 17 g. A landrace collected in Kenya has the highest seed mass in the world collection: 26.92 g per 100 seeds, exceeding the previous record of 26.47 g from a Tanzanian landrace (Remanandan et al. 1982). The range reported is 7.68 to 26.92 g. The seeds are plain white or beige, mottled, speckled, or mottled and speckled. Seeds are round or oval-shaped. Landraces from the coastal lowlands showed wide variability in seed size and seed coat color (from black to white), possibly due natural outcrossing with introductions from the Indian sub-continent.

Disease and insect resistance. Traditionally, farmers have been growing pigeonpea year after year in the same field. As a result fields have become natural wilt-sick plots. This may have resulted in high selection pressure in favor of wilt resistance. Some local landraces such as KO-31 and ICEAP 00040 showed high levels of resistance in successive evaluations in a wilt-infested field at Kiboko. There is some variability in insect pest damage with some genotypes showing limited susceptibility and others showing severe damage. It is possible that local germplasm may have different degrees of tolerance to insect pests.

Breeding

The breeding component of the program has focused on creating new populations combining wilt and leafspot resistance, seed characteristics, phenology, growth habit, and adaptability to intercropping systems. Well-adapted cultivars such as NPP 670, ICPL 87091, Kat 60/8, ICP 6927, and ICEAPs 00068,00020, and 00040 are used as parents. The crossing block has 41 parental lines including landraces, advanced breeding lines from the region, and accessions from ICRISAT. They represent considerable variability from the African and Asian genepools. Crossing is carried out in insect-proof greenhouses at Kabete Field Station. Over 24 F_2 populations, 11 three-way and 17 double-cross populations combining various desirable traits have been created. The segregating populations are being selected for wilt resistance using artificial inoculation at Kabete and wilt-sick plots at Kiboko. Selection for other characters is being carried out at the National Horticultural Research Centre, Thika. The populations will be advanced through gamete selection and bulk breeding procedures in a multiple constraint breeding strategy.

A second component of the breeding program involves selection of segregating populations under sole cropping and when intercropped with maize. The base population originated from crosses between short-duration, white-seeded ICRISAT lines and large-seeded, wilt-resistant African landraces. The F_2 to F_4 generations were advanced in wilt-sick fields at Kiboko to identify recombinants with wilt resistance. The F_5 lines were separated into four bulk populations on the basis of growth habit and maturity. The four populations were subjected to two cycles of selection under both sole and intercropped conditions in the 1998/99 and 1999/2000 short rains at Thika. The selected lines will be further evaluated to determine the effect of cropping system on their performance.

A third component of the program involved pedigree selection with progeny testing from other breeding nurseries and variety evaluations. Several early, early-medium, and medium-duration lines have been selected both in Kenya and Uganda in the last 2 years. Preliminary yield trials are planned during the 2000/01 short rainy season. The fourth part of the program has focused on inheritance of wilt resistance and other qualitative and quantitative traits. This work is reported by Odeny elsewhere in this publication.

Crop Protection

Disease and pest management research in this project has focused on identifying and characterizing pathogenic variation of *Fusarium udum* using morphological and cultural characteristics, pathogenicity on different pigeonpea varieties, and with amplified fragment length polymorphism (AFLP). Pest management studies have been carried out to determine the efficacy of botanicals in reducing yield losses, especially in intercrop systems. Results of this work are reported by Smith et al. elsewhere in this publication.

Crop Management and Socio-Economic Aspects

Studies in crop management were designed to identify practices that would optimize productivity in intercrop systems. They are described by Mergeai et al. elsewhere in this publication.

References

Kimani, P.M., Mergeai, G., Baudoin, J.P., and Smith, C. 2000. Collection of pigeonpea landraces from Coastal, Eastern and Central regions of Kenya (unpublished manuscript).

Remanandan, P.A., Shakoor, A., and Ngugi, E.C.K. 1982. Pigeonpea germplasm collection mission in Kenya, Sep-Oct 1982. Patancheru 502 324, Andhra Pradesh, India: Genetic Resources Unit, ICRISAT. 40 pp.

Recent Developments in Pigeonpea Breeding in Uganda

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Introduction

Pigeonpea is considered the most important grain legume in northern Uganda and the second most important (after cowpea) in the northeast. Despite the importance of the crop to a large section of the population both as a source of income and a diet supplement, research efforts in recent years have been limited. Apparently all the short-duration cultivars developed in the 1970s have been lost and only long-duration (6-9 months) landraces can be found - Apio Elena, Adong, Adyang, and Agogi. These landraces give low yields on farmers* fields: 300-600 kg ha^{-1}, compared to over 2.51 ha^{-1} achievable on-station with new high-yielding cultivars (Obuo et al. 1996).

Pigeonpea research in Uganda was initiated at Makerere University in 1968 with a grant from the Rockefeller Foundation. Over 5000 lines were introduced from all over the world and these formed the basis for a subsequent research program that included breeding work and allied studies. The main objective of the breeding program then, was to develop high-yielding short-duration cultivars adapted to Ugandan conditions. Considerable success was achieved and a number of promising advanced lines were identified. Other work included: a search for male sterility, studies on disease resistance, and development of composite materials (Musaana et al. 1992).

Recent Efforts in Crop Improvement

Pigeonpea research efforts were abandoned in 1979 and resumed only in 1989 following the initiation of the Pigeonpea Improvement Project for Eastern and Southern Africa by ICRISAT, with funding from the African Development Bank. The project has implemented some work in Uganda. Silim et al. (1991, 1993) conducted surveys on traditional farming systems, the predominant pigeonpea cultivars, and the most important pest and disease problems in the major pigeonpea-growing areas. The surveys revealed that production in traditional farming systems was very low, but could be improved by adopting better genotypes, better farming systems, and finding the most appropriate and cost-effective means of pest control. Out of these surveys came a recommendation to resume pigeonpea research in Uganda.

Surveys were also carried out in Aug-Sep 1997 under a project sponsored by the European Union. The surveys were implemented using a PRA approach and semi-structured questionnaires. The main objective of this project was to identify the major cropping systems and production (biotic or abiotic) constraints to pigeonpea, and develop

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cheap and cost-effective pest control packages. To achieve these objectives, research was initiated at three locations: Makerere University Agricultural Research Institute at Kabanyolo (MUARIK), Serere Agriculture and Animal Research Institute (SAARI), and Ngetta experimental station to assess the performance of the new short-duration, high-yielding selections in both sole and intercrop systems, and their response to pest attack.

Screening trials

During the 1990s, varieties were screened for agronomic traits, yield characters, adaptation to farming systems in north and northeastern Uganda, time to maturity (short- and medium-duration lines selected), and insect resistance. Over 200 breeding lines from ICRISAT and Nairobi University were evaluated at Serere and a few lines identified for on-farm testing. Kat 60/8, ICPL 87091, and ICP 6927 were found adapted to intercrop situations and recommended for restricted release (Okurut-Akol et al. 1996). Several genotypes are also currently being evaluated to identify lines with good intercropping ability.

Kat 60/8, ICPL 87091, and ICP 6927 were evaluated during the 1997B and 1998A seasons in intercrops with finger millet and sorghum. The results showed that row ratios of pigeonpea:finger millet/sorghum of 2:2 were the optimal combination, giving Land Equivalent Ratios of up to 1.6 (Rubaihayo et al. 2000). Similar results were later reported in the 1999 seasons at both MUARIK and Ngetta (Owere 2000). These results clearly suggest that the new pigeonpea lines are compatible in the pigeonpea/finger millet and pigeonpea/ sorghum intercrops common in the traditional system.

Eighty-four lines selected from screening trials at MUARIK and SAARI were planted in the 1999B season and evaluated for yield, agronom c characteristics, and pest damage. The results are being analyzed. The crop was ratooned in the 2000A season to determine the ratoonability of the lines. The selected lines will be tested for their intercropping ability.

Genetic fingerprinting

A collection of the African and Asian pigeonpea germplasm is being screened using the AFLP technique. African and Asian landraces and two local accessions were planted in the 2000A season for this study. This study will help determine the genetic diversity and evolutionary relationship between the Asian and African accessions, which will help in further research in pigeonpea breeding.

Pest management

Observations on pest management indicated that for optimal (cost-effective) control, pigeonpea should be sprayed at the following times: ICPL 87091 during flower bud initiation to pod formation, Kat 60/8 during pod formation to pod maturity (Rubaihayo et al. 2000). The results also indicated that determinate lines like ICPL 87091 were more susceptible to pest attack than indeterminate lines like Kat 60/8. Akongo (2000) has shown that intercropping pigeonpea with finger millet at different spatial arrangements had no effect on pod borers, while pod-sucking bugs were significantly ($p<0.05$) reduced in a pigeonpea:finger millet intercrop, 3:3 row pattern. Studies on the effect of plant extracts neem and Tephrosia showed a significant ($p<0.05$) reduction in pod damage, with greater reduction of damage at higher concentration of the plant extracts. The results further indicated that Tephrosia was more cost-effective than neem.

Acknowledgments

A part of the research work reported in this paper was funded by the European Union under the project "Genetic improvement of pigeonpea and management of intercropping systems in the semi-arid areas of East Africa" (Contract no. ERBICIC 18CT 960130).

References

Akongo, T. 2000. Effect of cropping systems, planting time and use of different spray materials on pest dynamics and damage of major pigeonpea field pests. MSc thesis, Makerere University, Uganda.

Musaana, M.S., Osiru, D.S.O., and Silim, N.M. 1992. Pigeonpea production and research in Uganda. International Pigeonpea Newsletter 16 (Aug 1992):37-40.

Obuo, J.E., Okurut-Akol, F.H., and Silim, S.N. 1996. Effect of spacing on yield of two pigeonpea cultivars in Uganda. Pages 98-100 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Okurut-Akol, F.H., Silim, S.N., and Opio, C. 1996. Pigeonpea on-farm research and demonstrations in northern Uganda. Pages 101-103 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Owere, L. 2000. Effect of row pattern and plant population on different pigeonpea cultivars intercropped with finger millet. MSc thesis, Makerere University, Uganda.

Rubaihayo, P.R., Osiru, D.S.O., and Okware, P. 2000. Performance of pigeonpea and its finger millet and sorghum intercrops. African Crop Science Journal 8(1): 49-62.

SUim, 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). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Silim, N.M., Musaana, M.S., Ugen, M.A., and Areeke, T.E.E. 1993. Survey of pigeonpea production and post-production systems in three districts of Uganda. Pages 67-73 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 25-27 Oct 1993, Bulawayo, Zimbabwe (Silim, S.N., Tuwafe, S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Discussions - Technology Development

Introduction of short-duration material

Long-duration varieties were part of the traditional cropping system in Eastern and Southern Africa. In addition to medium- and long-duration varieties, the Pigeonpea Project sought to promote short-duration varieties that were new to the region. This was done for three reasons.

- There was a clear need to improve yield and other characteristics of pigeonpea in traditional cropping systems. In research terms it was easier to improve the phenology of short-duration varieties (and thus fit them into traditional systems) than to improve yield and other characteristics of medium- and long-duration varieties.
- Considerable experience and germplasm was available from ICRISAT-India on high-yielding short-duration pigeonpea.
- Although most indigenous germplasm was of long duration, some lines with medium and short duration were collected from Eastern Africa, which could provide a base for genetic improvement.

Note that the Project did not focus exclusively on short-duration varieties. Considerable effort went into medium- and long-duration types: disease/pest management, phenology, adaptation, yield, ratoonability, and other farmer-preferred characteristics.

Both short and medium/long duration groups have their advantages and disadvantages. In terms of adoption, it may be easier to promote a crop type that promises a large, visible difference (e.g. earliness) rather than new medium- or long-duration types where improvements will be incremental and not always apparent to farmers. On the other hand, medium- and long-duration types could be promoted by emphasizing the continuous harvest they provide, in addition to other benefits such as fuelwood, nitrogen fixation, suitability for intercropping, and ratoonability.

Variety release

Variety releases are sometimes targeted at the wrong regions or the wrong socio-economic groups (e.g. ICPL 87091 in Uganda). Varieties are usually released for cultivation country-wide, although targeted release in a few districts would be more appropriate. In some cases farmers, after growing a released variety that is unsuitable for the area (either poorly adapted or not suited to local cropping priorities), are skeptical about new research products.

A new variety must be released together with a management package, without which farmers will be unable to benefit fully from the high yield potential of the variety. For example, varieties are tested on-farm with pest management, but released without accompanying recommendations on pest control.

Phenology

Manipulation of phenology does not necessarily mean accelerating the growth cycle, but adjusting the cycle to maximize benefits. For example, in cool areas away from the equator, long-duration types may flower or mature before the maize harvest. In such cases it is necessary to slow down their phenology to avoid competition in the maize/pigeonpea intercrop.

Crop Protection

Inheritance of Resistance to Fusarium Wilt in Pigeonpea

D A Odeny[1]

Introduction

Pigeonpea is one of the major pulse crops of the tropics and sub-tropics. It performs well in marginal environments and has the inherent ability to withstand environmental stresses, especially drought. In recent years, it has become one of the most sought after crops in plant introduction trials aimed at bringing new areas under cultivation. This is due to its ability to grow and produce grain under conditions where most other crops do not survive. Despite its importance in Kenya and elsewhere in the region, little concerted research effort has been directed at either crop improvement or technology transfer. Yields on farmers' fields are low and a number of factors are responsible - drought, lack of improved cultivars, poor crop husbandry, pests, and diseases (Ndiritu 1994).

Pigeonpea diseases have been reported to be of minor importance in the past in Eastern Africa (Acland 1971). However, recent surveys in major pigeonpea-growing areas of Kenya show that fusarium wilt and cercospora leaf spot are diseases of economic concern (Kannaiyan et al. 1984, Songa et al. 1991). Fusarium wilt (*Fusarium* udum Butler) is the most important soilborne disease throughout the pigeonpea growing areas of Kenya - average reduction in plant stand of 10% (Songa et al. 1991) and 16% (Kannaiyan et al. 1984) have been reported. Surveys carried out in 1980 estimated wilt incidence to be 60% in Kenya, 36% in Malawi, and 24% in Tanzania with annual losses of US$ 5 million in each of these countries (Subrahmanyam and Tuwafe 1995). Although it has been suggested that wilt incidence can be reduced by various practices, for example pigeonpea-cereal rotation, fallow, green manuring, zinc application, rotation with tobacco, and time of planting, host-plant resistance is probably the cheapest and most effective management practice.

Understanding the inheritance of characters in pigeonpea would enable breeders to improve selection efficiencies with respect to a particular trait. Inheritance of fusarium wilt resistance is not well understood. Relatively little work has been reported on the genetics of resistance despite the fact that breeding programs aimed at developing wilt-resistant pigeonpea have been conducted since the early 1900s. The few reports available are conflicting and have failed to provide a complete picture of the genetics of resistance beyond indicating that a few genes are involved (McRae and Shaw 1933, Green et al. 1981). It is only when this is known that a correct breeding program can be designed. This experiment was carried out in order to achieve this objective.

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Materials and Methods

Four wilt-resistant lines (ICP 8863, ICPL 87119, ICEAP 00040, ICEAP 00536) and four susceptible lines (Kat 60/8, NPP 670, ICPL 93027) were studied. All the parental lines were grown under glasshouse conditions. A single 3 m row for the first planting, double 3 m rows for the second planting, and triple 3 m rows for the last planting represented each cultivar. Planting was done at an interval of 1 month to ensure synchronization of flowering among the early, medium, and long-duration groups. Frequent weeding and spraying against insects and diseases was done to reduce losses.

Crossing. Crossing was done under glasshouse conditions using hand emasculation and pollination. F_1 seeds were divided into three. The first lot was planted and allowed to self and F_2 harvested. The second lot was planted and backcrossed to both the resistant and susceptible parents. The third lot was kept.

Evaluation for resistance. All the F_2, Backcross 1 (BC_1), Backcross 2 (BC_2), and F_1 were evaluated in sick pots under glasshouse conditions. BC_1 was a cross between F_1 and the resistant parent while BC_2 was a cross of F_1 to the susceptible parent. On average, 40 seeds each for the parents and F_1, 200 seeds for the F_2 and 40 seeds for each backcross generation were used.

Preparation of inoculum. An isolate of the fusarium wilt fungus from Kiboko, a major pigeonpea-growing area in Kenya, was used. A single conidial culture was multiplied on 100 mL of potato dextrose broth in a petri dish that was placed on a rotary shaker for 10 days at 25-30°C. The contents of the flask were diluted with sterile distilled water to a final inoculum concentration of 1×10^6.

Preparation of the pots. Soil was mixed with sand at a ratio of 3:1, respectively. The mixture was sterilized in an autoclave for 4 h. It was then placed in pots in the glasshouse. Seeds were first pre-germinated in sterile riverbed sand. The seedlings were transplanted a week after germination. The pots containing soil and sand mixture were thoroughly watered a day before transplanting. Moisture level was maintained at or near field capacity. The inoculum was harvested and placed in a beaker. During transplanting, the seedlings were gently removed from the sand, the roots cleaned, then trimmed with a sterile surgical blade, and dipped into the inoculum for 10 minutes before finally transplanting into the pots. The roots were trimmed to provide a point of entry for the pathogen. Controls of both susceptible and resistant lines were used for every batch. The controls were divided into two lots: one inoculated and the other non-inoculated. Pots were kept in the glasshouse for two months and wilting of the host observed. The pathogen was re-isolated from the wilted plants and its pathogenicity re-confirmed.

Data collection and plot design. All the test lines were grown in a randomized complete block design with four replicates. Disease onset and progress was monitored and the wilted plants recorded every week for 2 months. A 1-9 disease scale was used, where 1 = no visible symptoms and 9 = very severely diseased or dead. The various segregation ratios were calculated and tested using Chi-square ($P < .05$).

Results and Discussion

The fourth week data was considered the most reliable to use in the analysis because during this period, all the susceptible controls had wilted. Results are shown in Tables 1,2, and 3.

In Table 1, data from one cross (ICPL 93027 x ICEAP 000536) showed 9S:7R (susceptible/resistant) segregation ratios for the F_2,1:1 for backcross 1, and all susceptible for backcross 2. This confirmed a case of duplicate recessive genes for resistance with the following possibilities:

Resistant parent	aabb
Susceptible parent	AABB
F_1	AaBb
F_2 - 9/16: Susceptible	A_B_
7/16: Resistant	A_bb, aaB_, aabb

Table 2 gave a segregation ratio of 13:3 for the F_2, 1:1 for BC_1 and all susceptible for BC_2. This meant that for this particular cross, there was complete dominance at both gene pairs but the susceptibility gene when dominant was epistatic to the resistant gene. Therefore the dominant A gene for resistance did not produce an effect in the presence of a dominant susceptibility gene (inhibitor). The possible genotypes therefore were:

Susceptible parent	aaBB
Resistant parent	AAbb
F_1	AaBb (susceptible)
F_2	A_bb: 3/16 resistant
	A_B_: 9/16 susceptible
	AaB_: 3/16 susceptible
	Aabb: 1/16 susceptible

Table 3 gave segregation ratios of 10:6 for F_2, 1:1 for $BC_1$and 1:3 for BC_2. This meant that for all the crosses included in Table 3, there was partial dominance at both gene pairs and that for each partially dominant gene, there was an additive effect. Resistance would therefore be at different levels. Possible genotypes were:

AAbb - Susceptible parent
aaBB - Resistant parent
AaBb - F_1: Susceptible
F_2 would have the following segregation:
1/16: AABB - Resistant level 10
2/16: AABb - Resistant level 8
2/16: AaBB - Resistant level 7
1/16: AAbb - Resistant level 6
4/16: AaBb - Resistant level 5
1/16: aaBB - Resistant level 4
2/16: Aabb - Resistant level 3
1/16: aabb - Resistant level 1

The first four resistant levels were considered resistant while the last four were susceptible.

Table 1. Segregating ratio between wilt-resistant and susceptible plants in various generations and backcrosses.

		Observed		Expected			
Pedigree	Generation	R*	S*	R*	S*	X^2	P
ICPL 93027	P1	-	56		56		
ICEAP 000536	P2	148	-	148			
ICPL 93027 x ICEAP 00536	F_1	-	14		14		
ICPL 93027 x ICEAP 00536	F_2	38	59	42	55	0.67	5%
F_1x ICEAP 000536	BC_1	3	9	3	9	-	
F_1x ICPL 93027	BC_2	-	14		14		

Table 2. Segregating ratio between wilt-resistant and susceptible plants in various generations and backcrosses.

		Observed		Expected			
Pedigree	Generation	R*	S*	R*	s*	X^2	P
NPP 670	P1	-	65	-	65		
ICEAP 00040	P2	24	-	24	-		
NPP 670 x ICEAP 00040	F_1	-	71	-	71		
NPP 670 x ICEAP 00040	F_2	30	147	33	144	0.33	5%
F_1x ICEAP 00040	BC_1	6	11	8.5	8.5	1.46	5%
F_1x NPP 670	BC_2	-	35	-	35	-	

Table 3. Segregating ratio between wilt-resistant and susceptible plants in various generations and backcrosses.

		Observed		Expected		
Pedigree	Generation	R*	s*	R*	S*	X^2
Kat 60/8	P1	-	38		38	
ICPL 87119	P2	49	-		49	
Kat 60/8 xICPL 87119	F_1	-	14		18	
Kat 60/8 x ICPL 87119	F_2	74	133	78	129	0.33
F_1x ICPL 87119	BC,	28	35	31.5	31.5	0.78
F_1x Kat 60/8	BC_2	16	43	15	45	0.17
Kat 60/8	P1	-	20		20	-
ICP 8863	P2	51	-	51		-
Kat 60/8 x ICP 8863	F_1	-	17		17	-
Kat 60/8 x ICP 8863	F_2	82	135	81	136	0.0196
F_1x ICP 8863	BC_1	7	10	8.5	8.5	0.029
F_1x Kat 60/8	BC_2	10	34	11	33	0.324

R* = resistant, S* = susceptible
Chi at 5% level of confidence, 1 df = 3.84

The differences in the segregation values seen above for Tables 1, 2 and 3 could be explained by the fact that the source of resistance used in every table was of different origin. In Table 1, the source of resistance was of African origin but had been improved using Indian material. In Table 2, the source of resistance was of East African origin. The rest were rather uniform because the sources of resistance were all of Indian origin.

The results from these experiments showed that the genes for this trait are controlled differently depending on the origin of the resistance source used in a particular cross. It was also observed that there are genetic differences between pigeonpeas of Indian origin and those of African origin.

References

Acland, J.D. 1971. East African crops. Rome, Italy: Food and Agricultural Organization of the United Nations (FAO).

Green, J.M., Sharma, D., Reddy, L.J., Saxena, K.B., Gupta, S.C., Jain, K.C., Reddy, B.V.S., and Rao, M.R. 1981. Methodology and progress in the ICRISAT pigeonpea breeding program. Pages 437-449 *in* Vol.1, Proceedings of the International Workshop on Pigeonpea, 15-18 Dec 1980, Hyderabad, India. Patancheru 502 324, Andhra Padesh, India: ICRISAT.

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.

Mc Rae, W. and Shaw, F.J.F. 1933. Influence of manure on the wilt disease of *Cajanus cajanicus* Spreng. II. The isolation of resistant types. Scientific Monograph, Imperial Council of Agricultural Research, Pusa 7:37-68.

Ndiritu, C.G. 1994. Welcome address. Pages 1-2 *in* Improvement of Pigeonpea in Eastern and Southern Africa. Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Nene, Y.L., Kannaiyan, J., and Reddy, M.V. 1981. Pigeonpea diseases: resistance screening techniques. Information Bulletin No. 9. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Songa, W.A., King, S.B., and Omanga, P.A. 1995. Pigeonpea pathology research in Kenya. Pages 30-37 *in* Improvement of Pigeonpea in Eastern and Southern Africa, Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Yield Losses due to Field Pests and Integrated Pest Management Strategies for Pigeonpea - a Synthesis

E M Minja[1]

Introduction

Pigeonpea is a major legume crop in the tropics and sub-tropics, and accounts for 5% of world legume production (Hillocks et al. 2000). It is still a neglected crop in terms of the amount of research done on it, despite its many uses. There is great potential for the expansion of the crop in the semi-arid regions of Africa, where it could counteract declining soil fertility. One main constraint to expansion of pigeonpea production is its susceptibility to insect pests and diseases. The most important insect pests in the region are those that attack the crop at the reproductive stage and during storage; they include the pod-sucking bugs (dominated by *Clavigralla tomentosicollis* Stal), pod borers (*Helicoverpa armigera* Hubner, *Maruca vitrata* (= *testulalis*) Geyer, *Etiella zinckenella* Treitschke, *Lampides* spp), pod fly (*Melanagromyza chalcosoma* Spencer), and bruchids (*Callosobruchus* spp) (Table 1).

Considerable work has been done by national programs in Eastern and Southern Africa and by ICRISAT in developing high yielding short-, medium-, and long-duration pigeonpea

Table 1. Major field insect pests on pigeonpea in Kenya, Malawi, Tanzania, and Uganda.

		Pest status*			
Order/Scientific name	Family	Kenya	Malawi	Tanzania	Uganda
Diptera					
Melanagromyza chalcosoma Spencer	Agromyzidae	1	3	1	1
Hemiptera					
Clavigralla tomentosicollis Stal	Coreidae	1	1	1	1
Lepidoptera					
Helicoverpa armigera Hubner	Noctuidae	1	1	1	1
Maruca vitrata (= *testulalis*) Geyer	Pyralidae	1	1	2	1
Etiella zinckenella Treitschke	Pyralidae	2	2	2	2

* 1 = Serious, widely distributed, causes heavy economic losses. 2 = Common, causes widespread concern. 3 = Occasionally serious, sporadic or of local importance

Source: Minja et al. 1999

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genotypes. These have been tested at various locations in each country. The short-duration genotypes have great potential in areas with reliable irrigation and can escape drought in a truncated rainy season. However, the determinate types that mature in 3-4 months have disadvantages to smallholder farmers because their determinancy makes them more vulnerable to flower- and pod-feeding insects.

Yield losses due to field insect pests on pigeonpea in farmers' fields in Eastern and Southern Africa during 1995/96 are shown in Table 2. Analysis of damage levels by each pest group indicated that pod-sucking bugs caused more damage in Malawi and Kenya, while pod borers caused more damage in Tanzania and Uganda (Table 3). Pod fly caused more damage in Kenya than in the other countries. Pod fly damage was high in crops maturing during cool weather; pod borer damage was high on crops maturing during warm weather, and damage from pod-sucking bugs was high regardless of weather conditions. Greater variations in losses were observed between locations in Kenya, Malawi, and Tanzania than in Uganda. Warm and dry locations had smaller yield losses than warm and humid, cool and dry, or cool and humid locations (Minja et al. 1999).

Losses Associated with Pest Groups

Pod-sucking Hemiptera

A large number of Hemiptera, mainly in the families Alydidae, Coreidae, and Pentatomidae, feed on pigeonpea and are commonly referred to as pod-sucking bugs (Lateef and Reed 1990). A few species are widespread and serious pests of pigeonpea. The most important are coreids, *Clavigralla* (= *Acanthomia*) spp, *Anoplocnemis* spp, *Riptortus* spp, and *Mirperus* spp. Research efforts have concentrated on three *Clavigralla* species:

Table 2. Mean yield losses (%) due to field insect pests on pigeonpea in farmers' fields, 1995 and 1996.

Country	Mean yield loss
Uganda	16
Kenya	22
Tanzania	14
Malawi	15

Table 3. Contribution (%) of field pest groups to pigeonpea yield losses in four countries.

Pest group	Uganda	Kenya	Tanzania	Malawi
Pod-sucking bugs	30	52	47	69
Pod borers	53	22	50	28
Pod fly	17	26	3	3

C. tomentosicollis Stal which is widespread in sub-Saharan Africa, *C. scutellaris* Westwood which is found from Kenya through Yemen, Oman, Pakistan and India (Dolling 1979), and *C. gibbosa* Spinola which is restricted to India and Sri Lanka. Three additional *Clavigralla* species are also associated with pigeonpea: *C. shadabi* in Western and Central Africa, C. *elongata* Signoret in Eastern and Southern Africa, and C. *horrida* Germar in Zimbabwe and South Africa. The last two species are similar and often confused in the field and in literature (Shanower et al. 1999).

Adults and nymphs feed on pigeonpea by piercing through the pod wall and extracting nutrients from the developing seeds. Damaged seeds are dark and shriveled, they do not germinate, and are not acceptable for human consumption (Materu 1970). In Tanzania, Materu (1970) reported that more than 50% of pigeonpea seeds were disfigured and unmarketable because of pod-sucking bug damage. In Malawi, pod-sucking bugs accounted for 60% and 75% of pigeonpea seed losses in farmers' fields in 1995 and 1996, respectively. In Kenya, Tanzania, and Uganda losses ranged between 35 and 65% (Minja 1997).

Pod-feeding Lepidoptera

Worldwide, over 30 species of Lepidoptera in six families feed on the reproductive structures of pigeonpea (Shanower et al. 1999). The most important species in Eastern and Southern Africa are *Helicoverpa armigera, Maruca vitrata, Etiella zinckenella,* and *Lampides* spp. *H. armigera* larvae feed on seedling foliage, flower buds, flowers, and developing seeds. *M. vitrata* and *Lampides* larvae feed on flower buds, flowers, and developing seeds. *E. zinckenella* larvae feed on maturing and drying seed inside the pods. No detailed studies have been conducted on pigeonpea pod borers in the region. Results from surveys in farmers' fields in Kenya, Malawi, Tanzania, and Uganda, and on-station trials in Kenya and Malawi, have indicated that pod-feeding Lepidoptera larvae accounted for 5-35% of the seed losses on pigeonpea genotypes (Minja 1997).

Seed-feeding Diptera

The larva of the pigeonpea pod fly, *Melanagwmyza chalcosoma,* feed on developing seeds within the pod (Minja 1997). A second species, *M. obtusa* Malloch, appears to be restricted to Asia. Both species feed only on pigeonpea and related species within the subtribe Cajaninae. Pod fly damage has been reported from several countries. Extensive studies have been conducted on *M. obtusa* in Asia (Shanower et al. 1998). Although *M. chalcosoma* has not been studied as extensively, it seems to occupy a similar ecological niche (Minja 1997). The difference between these two species is that a single seed locule contained more than 2 larvae/pupa of M. *chalcosoma* (up to 40 larvae/pupa were observed per pod of five seeds in Kenya) compared to 1 or 2 for *M. obtusa* in India. In Eastern and Southern Africa, pod fly accounted for up to 4%, 7%, 13%, and 46% of seed losses in Malawi, Tanzania, Uganda, and Kenya, respectively (Minja 1997).

Influence of Sowing Date on Yield Losses

The influence of sowing date on yield losses was studied at three locations in Kenya. Two short-duration genotypes, determinate ICPL 87091 and indeterminate Kat 60/8, were sown in Nov, Jan, and March at Kiboko. The Jan and March sowings were planned to coincide with the maturity times for medium- and long-duration genotypes, respectively. In another study, short-, medium-, and long-duration genotypes were sown at Mtwapa (50 m altitude), Kiboko (920 m), and Kabete (1825 m). The crops were grown with and without insecticides to enable the assessment of avoidable yield losses.

Mean grain yield losses increased with delayed sowing: 62%, 68%, and 74% respectively for Nov, Jan, and Mar sowing dates (Table 4). Grain yield losses for Kat 60/8 were similar for different sowing dates, while losses on ICPL 87091 increased with delay in sowing. Mean yield losses across locations were similar, 40-46% in crops planted in April at Mtwapa, March at Kiboko, and Oct at Kabete (Table 5).

Yield losses due to pod borers were higher on crops flowering and maturing during warm weather than on crops maturing during cool weather (Table 6). In contrast, losses due to pod fly were very low during warm weather and high during cool weather. Losses due to pod-sucking bugs were high in all weather conditions.

Table 4. Mean yield losses (%) due to field insect pests on two short-duration pigeonpea genotypes sown on different dates at Kiboko, Kenya, 1995 and 1996.

Genotype	Nov sown	Jan sown	Mar sown
1CPL 87091	63	70	82
Kat 60/8	60	67	67
Mean	62	68	74
SE±	1.7	1.3	2.6
CV (%)	11.7	9.2	17.1

Table 5. Mean pigeonpea yield losses (%) due to field insect pests at three locations in Kenya, 1995 and 1996.

Genotype	Mtwapa	Kiboko	Kabete
ICPL 87091	42	35	36
Kat 60/8	36	29	32
ICP 12734	39	43	64
KAT 81/3/3	45	51	53
Mean	40	40	46
SE±	1.2	2.8	3.4
CV(%)	10.1	15.7	34.4

Table 6. Mean yield losses (%) due to field pests on pigeonpea maturing at different dates at Kabete and Kiboko, Kenya.

	Kabete			Kiboko		
	Nov	Jan	Mar	Nov	Jan	Mar
Pod-sucking bugs	6	14	23	22	38	37
Pod borers	2	7	8	9	4	3
Pod fly	8	11	10	9	5	5

Management Strategies

Pigeonpea pest management is complicated by several factors. The crop is attacked by at least three pest groups with very different biologies. These differences include host range (oligophagous to highly polyphagous), apparency (feeding on the plant versus concealed feeding), and feeding mode (chewing versus piercing and sucking). The pests also have highly variable population dynamics across years and locations, and at least one, *H. armigera,* has developed high levels of resistance to several insecticides (Shanower et al. 1999). The key pests are all direct pests, feeding on the portion of the crop most valued by humans, and each is capable of completely destroying a crop. Economic thresholds have not been developed for any pest of pigeonpea. Another obstacle to progress in pigeonpea pest management is that it has been considered a marginal crop or is the neglected component of a mixed cropping system and is thus given less attention by farmers, crop protection specialists, and policy makers.

The primary focus of pigeonpea pest management has been on *H. armigera* and *M. obtusa* in India, with emphasis on chemical control and host plant resistance (Lateef and Reed 1990). A major change in farmers' pest management practices has been the widespread adoption of synthetic pesticides as the primary method of pest control in some areas (Shanower et al. 1999). In India, calendar sprays are recommended and followed, with the first application at 50% flowering and the second and third applications at 15-day intervals. Farmers in southern India now apply pesticides 3-6 times per season (Shanower et al. 1999). This change has occurred over a period of about 10 years, and there are indications that pigeonpea farmers in Africa may follow a similar trend (Minja 1997). The rapid increase in pesticide use on pigeonpea is alarming and emphasizes farmers' concern with insect pests. The trend also highlights the need for safe and effective management strategies.

The use of alternative insecticides such as plant-derived products (e.g. neem, *Azadirachta indica*) and insect pathogens, particularly the *Helicoverpa* nuclear polyhedrosis virus (NPV), is considered to be safer for humans and the environment, and to cause less damage to beneficial organisms than conventional insecticides. Neem products have traditionally been used in storage in India. Commercially formulated neem products are available in many countries, although results on pigeonpea have been inconsistent. The use of NPV to control *H. armigera* has received much attention, particularly in India, though reliable control on pigeonpea has not been obtained (Shanower et al. 1999). Both neem and NPV products suffer from poor and highly variable quality and a more limited distribution network than conventional insecticides. These problems must be overcome before these products can be considered effective and practical alternative control methods. The possibility of farmers or farmer cooperatives producing and using plant-derived or insect pathogen products on a local scale should attract the attention and resources of a number of organizations.

The development of insect-resistant and/or tolerant genotypes has been a high priority for both national and international research programs for many years. Pigeonpea lines with resistance to either or both pod borers and pod fly have been reported, but little progress has been made in incorporating resistance in genotypes that are widely cultivated by farmers. Frequently the resistant lines are less preferred in terms of taste, seed color, and/or size, and are often susceptible to diseases (Shanower et al. 1999).

Traditional pigeonpea landraces are medium- to long-duration and may have been selected to avoid peak pest attack. Selecting companion crops or cultivars has also been investigated as a means to minimize pest damage (Lateef and Reed 1990). The widespread practice of intercropping longer-duration pigeonpea genotypes with one or more companion crops may have evolved through farmers' desire to reduce risks of insect or other losses. The companion crops are usually harvested before pigeonpea flowers. Thus, when pigeonpea is most attractive to the key pests, it is functionally a sole crop and there is seldom any reduction in pest damage relative to sole-cropped pigeonpea (Shanower et al. 1999). Recently developed short-duration pigeonpea genotypes, which mature in less than 4 months, may offer new opportunities for cultural or agronomic manipulations to minimize insect damage.

Improving the impact of natural control agents is perhaps the most neglected area of pigeonpea pest management research. Although a number of natural enemies have been recorded from the key pests of pigeonpea (Minja et al. 1999, Shanower et al. 1999), little is known of their effect on pest population dynamics. No reliable or comprehensive life table study has been published that evaluates the role and impact of natural enemies of any insect pest on pigeonpea. A number of pigeonpea characters that inhibit natural enemies have been identified. Developing genotypes that lack these characters would be a practical approach to improving natural enemy impact. Much more needs to be known of the pests and their natural enemies, particularly in this region, before the feasibility of natural enemy impact can be determined.

Knowledge of the impact, dynamics, and ecology of the pests and their natural enemies is essential before effective control strategies can be developed. These studies must focus on cropping systems as pigeonpea is frequently one component of a complex farming system. Other tropical legumes are particularly important because they share a number of pests and natural enemies with pigeonpea. There is no short-cut or magic bullet to reduce losses due to insect pests immediately. Progress will be incremental, and in the short term, the greatest impact may come from improving insecticide application. This would involve enhancing the skills needed to scout fields and properly mix and apply insecticides and providing unbiased information on the relative risks and benefits of different insecticides. A strategy for the medium term should concentrate on developing improved genotypes that combine high yield and disease and insect resistance into backgrounds with consumer-and market-preferred agronomic characters. Longer term solutions must focus on ways to enhance natural enemy control processes, either by introducing exotic natural enemy species or by enhancing the effectiveness of endemic species.

References

Dolling, W.R. 1979. A revision of the African pod bugs of the tribe *Clavigrallini* (Hemiptera: Coreidae) with a checklist of the world species. Bulletin of the British Museum Natural History, Entomology 39:1-84.

Hillocks, R.J., Minja, E., Mbwaga, A., Nahdy, S.M., and Subrahmanyam, P. 2000. Diseases and pests of pigeonpea in eastern Africa: a review. International Journal of Pest Management 46(1):7-18.

Lateef, S.S. and Reed, W. 1990. Insect pests of pigeonpea. Pages 193-242 *in* Insect pests of tropical legumes (Singh, S.R., ed). Chichester, UK: Wiley.

Materu, M.E.A. 1970. Damage caused by *Acanthomia tomentosicollis* Stal and *A. horrida* Germar (Hemiptera: Coreidae). East African Agricultural and Forestry Journal 35:429-435.

Minja, E.M., Shanower, T.G., Songa, J.M., Ong'aro, J.M., Kawonga, W.T., Mviha, P.J., Myaka, F.A., Slumpa, S., Okurut-Akol, H., and Opiyo, C. 1999. Studies of pigeonpea insect pests and their management in Kenya, Malawi, Tanzania and Uganda. African Crop Science Journal 7:59-69.

Minja, E.M. 1997. Insect pests of pigeonpea in Kenya, Malawi, Tanzania and Uganda; and grain yield losses in Kenya: a consultant's report. PO Box 776, Bulawayo, Zimbabwe: ICRISAT. 65 pp.

Shanower, T.G., Romeis, J., and Minja, E.M. 1999. Insect pests of pigeonpea and their management. Annual Review of Entomology 44:77-96.

Shanower, T.G, Lal, S.S., and Bhagwat, V.R. 1998. Biology and management of *Melangromyza obtusa* (Malloch) (Diptera: Agromyzidae). Crop Protection 17:249-263.

Past and Current Studies on Ecology and Management of Insect Pests of Pigeonpea

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Introduction

Pigeonpea is an important source of protein in the drier areas of Uganda. Yields on farmers' fields average 300-600 kg ha^{-1}, compared to 1.4 t ha^{-1} obtained at experimental stations (MAAIF 1992). One of the causes of low pigeonpea yields in most regions of the world is heavy insect damage. Over 200 arthropod species have been reported to feed on the crop (Reed and Latif 1990), but most of these are regarded as minor (Reed et al. 1989). Insect pests damage all parts of the pigeonpea plant from roots to flowers, pods, and seeds. This paper summarizes previous and ongoing studies on the ecology and management of pigeonpea pests in Uganda.

Previous Work

Pest species

The earliest attempt to document insect pests of pigeonpea in Uganda was by Le Pelly (1959), who listed 51 species as feeding on the crop - 23 hemiptera, 23 lepidoptera, 1 dipteran, 3 coleoptera, and 1 orthopteran. Thirty-five years later, Night and Ogenga-Latigo (1994) recorded 19 insect species as either common or rare pests of pigeonpea in Uganda, of which they considered eight to be important -*Aphis craccivora, Clavigralla* sp, *Helicoverpa armigera, Maruca testulalis, Exelastis atomosa, Lampides boetius, Etiella zinckenella* and *Melanagromyza chalcosoma.* They claim to have found seven species as new records on the crop in the country. However, they did not study the distribution of the various species. More importantly, the study was conducted in a predominantly non-pigeonpea growing area, and therefore may not represent the correct or typical situation.

In 1995 and 1996, surveys conducted in farmers' fields in Uganda (Minja 1997) identified six insect species as the major field pests - *Melanagromyza chalcosoma, Clavigralla tomentosicollis, Etiella zinckenella, Helicoverpa armigera, Maruca testulalis,* and *Maruca vitrata.*

The difference in the number of species between these two studies may be due to differences in study areas and varieties: Minja studied mainly landraces, while Night and Ogenga-Latigo used improved short- and medium-duration varieties, which may be susceptible to a wider range of pests. Also, Night and Ogenga-Latigo considered all pests, while Minja focused on pests that occur regularly (as opposed to species that occur sporadically but cause heavy damage).

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Losses caused by insect pests

No detailed yield loss assessment studies have been conducted. However, Minja (1997) reported that 14% and 16% of pods in Apac and Lira districts respectively were damaged by pod borers; while sucking bugs were responsible for 3% and 6% seed damage in Apac and Lira respectively. Podfly caused 4.4% and 2.0% damage in Apac and Lira. Rubaihayo et al. (2000) demonstrated that applying chemical insecticides during the flowering and podding stages controlled damage due to pod-sucking bugs, pod borers, and pod fly, and resulted in a 43% increase in pigeonpea grain yield. However, no attempt was made to apportion the total losses among different pests, or to establish economic injury levels.

Control of insect pests

Surveys by Minja (1997) have shown that very few farmers in northern Uganda control field insect pests of pigeonpea. Apart from insecticides there are no established control methods for pigeonpea pests in Uganda.

Ongoing Research

It is apparent that information is lacking in several areas:

- Damage-yield relationships and threshold (economic) injury levels for different pests
- Appropriate intervention methods
- Population dynamics and ecology of insect pests.

Some of these aspects are being handled under the European Union Project, with additional funding from NARO, which focuses on pod borers and pod-sucking bugs. Project activities include:

- Effect of intercropping on population densities of pod borers and pod-sucking bugs
- Effect of planting time on pest incidence and damage
- Assessment of losses
- Effects of biorationals.

Effect of intercropping

Effects of intercropping pigeonpea with finger millet on pest occurrence/damage at podding were studied at two locations - Makerere University Agricultural Research Institute Kabanyolo (MUARIK) and Ngetta, a traditional pigeonpea-growing area. Two intercropping patterns and sole crop were studied. The intercrop patterns were (i) 2 rows of finger millet alternating with 2 rows of pigeonpea, (ii) 3 rows of finger millet alternating with 3 rows of pigeonpea.

Results are shown in Table 1. Pod borers were not affected by the intercropping pattern, but pod-sucking bugs were reduced by widely spaced pigeonpea rows. The proportion of seed damage was lowest in the 3:3 intercrop. Damage in the sole crop and the 2:2 intercrop were high and similar. Thus, while the data on 2:2 versus 3:3 patterns are not conclusive, it is likely that widely spaced rows (or groups of rows), e.g. 3:3, will reduce insect damage.

Table 1. Effect of intercropping on total percentage seed damage by pod and seed pests, MUARIK and Ngetta, Uganda.		
Cropping system	MUARIK	Ngetta
Sole crop	23.2 ±4	21.4 ±1.05
Millet:pigeonpea intercrop 2:2	22.8 ±2.1	23.8 ± 0.2
Millet:pigeonpea intercrop 3:3	19.5 ±2.7	17.0 ±2.7

Table 2. Effect of planting time on percentage seed damage by pod and seed pests, MUARIK and Ngetta, Uganda.

	Planting time	Pod borers	Pod-sucking bugs	Pod fly
MUARIK	Onset of rain	8.8 ±1.75	10.9 ± 3.75	1.7 ±0.2
	2 weeks after onset of rains	7.4 ±1.75	8.4 ±1.4	1.3 ±0.15
	4 weeks after onset of rains	4.9 ± 2.25	13.3 ±1.35	1.1 ±0.25
Ngetta	Onset of rain	9.9 ±3.60	13.1 ±2.95	5.3 ± 0.35
	2 weeks after onset of rains	8.8 ±0.70	11.0±1.0	4.6 ±0.45
	4 weeks after onset of rains	7.8 ± 2.45	15.5 ±0.55	3.1 ±0.55

Effect of planting date

Late planting increases damage by pod suckers but reduces damage by pod borers (Table 2). Thus, appropriate cultural practices will depend on the relative importance of the pests at a given location. This is true for planting date, and to some extent for intercropping pattern.

Effect of insecticide application on pest damage and yield

Application of dimethoate (400 g ai ha^{-1}) significantly reduced damage due to pod borer, pod suckers, and pod fly at both locations. This increased yields by 64% and 30% in the first and second rains respectively at MUARIK; and by 110% and 30% at Ngetta in the first and second rains respectively (Fig. 1).

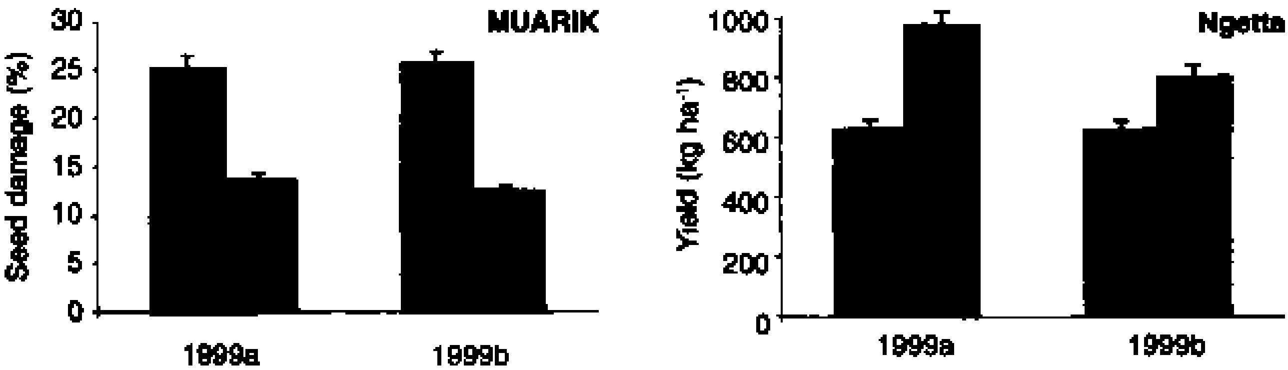

Figure 1. Effect of dimethoate application on pigeonpea yield and pest damage at MUARIK and Ngetta, first and second seasons 1999.

Effects of biorationals

The effect of neem and Tephrosia on pest population densities was studied. The chemicals were applied at three different concentrations - recommended rate, half the recommended and twice the recommended rate. Recommended rates are: dimethoate 400 g ai ha^{-1}, neem 36 g ai ha^{-1}, Tephrosia 134 kg leaves per ha.

Tephrosia and neem did not significantly reduce the population density of pod borers or pod-sucking bugs, while dimethoate significantly controlled the population density in both pests, the effect increasing with increasing concentration (Table 3).

Although the botanicals did not significantiy reduce pest population density, they reduced pod damage significantly. Better control was obtained at higher concentration of the botanicals.

The reduction in pod damage was reflected in higher yield. In all cases grain yield increased with increase in concentration of chemicals. Application of dimethoate gave better yields than biorationals. Applying dimethoate at double the recommended rate increased yield by 64%. At the highest concentration, applying Tephrosia resulted in higher grain yield than application of neem.

Table 3. Effects of neem and Tephrosia extracts on pigeonpea pest population, MUARIK and Ngetta, Uganda.

	Concentration	Pod borers per plant	% pod damage	Pod suckers per plant	% pod damage	Yield (kg ha-')
Muarik						
Untreated control	0	5.5	36.1	1.7	19.2	306.1
Neem	18	5.5	33.2	1.8	18.4	479.0
(g ai per ha)	36	5.0	23.3	1.7	15.7	583.3
	72	4.8	19.5	1.7	12.3	616.4
Fresh Tephrosia	67	5.6	27.7	1.5	18.0	458.3
(kg leaves per ha)	134	5.5	25.7	1.5	15.7	510.3
	268	4.8	19.3	1.7	8.6	671.9
Dimethoate	200	2.4	23.3	0.9	14.5	736.5
(g ai per ha)	400	1.9	13.3	0.1	9.5	839.2
	800	0.5	12.1		5.0	908.5
Ngetta						
Untreated control	0	2.0	42.8	1.8	34.7	155.0
Neem	18	1.8	33.3	1.4	19.7	263.9
(g ai per ha)	36	1.8	31.4	1.3	15.3	359.0
	72	1.7	21.0	1.5	10.9	374.9
Fresh Tephrosia	67	1.8	30.1	1.5	20.5	213.0
(kg leaves per ha)	134	1.8	27.4	1.5	13.8	270.3
	268	1.8	14.3	1.5	9.1	417.3
Dimethoate	200	1.1	7.4	0.8	21.8	695.6
(g ai per ha)	400	0.7	3.8	0.4	17.2	785.5
	800	0.6	2.2	0.2	7.7	875.5

Discussion

The present results indicate that damage caused by insect pests is significant and warrants control. In commercial farming, use of chemical insecticides would have been the solution. In such a situation the concern of the scientist would be to establish the economic threshold and economic injury levels of the various pests and thus determine the appropriate application rates.

Pigeonpea in Uganda is grown largely by subsistence farmers who cannot afford pesticides; cheaper control methods are therefore needed, and Tephrosia would appear to be appropriate. The present studies showed that both neem and fresh Tephrosia significantly reduced pod damage by the major insect pests; but benefit:cost analysis indicated that Tephrosia was more cost-effective. The campaign to plant Tephrosia shrubs in pigeonpea-growing areas needs to be intensified. However, we also need to look at the different methods of preparing Tephrosia at farm level, and select the best method.

The results have also demonstrated the effects of cultural practices on pest management. Intercropping did not affect pod borers, but reduced pod-sucking bugs. Early planting increased pod borer damage but reduced damage by pod suckers. Therefore to be able to utilize cultural practices in pest management, it is important to establish which group of pests causes most damage. This suggests the need for more detailed studies on the damage/yield relationship in different pest species.

The ecology of pod borers and pod-sucking bugs on pigeonpea has not been well studied in Uganda. Consequently the "push and pull" approach cannot be easily put to use. We need to understand what factors promote the colonization of pigeonpea (pull) and what discourages colonization (push). Understanding of these factors is a prerequisite for designing appropriate integrated pest management strategies.

Acknowledgments

A part of the research work reported in this paper was funded by the European Union under the project "Genetic improvement of pigeonpea and management of intercropping systems in the semi-arid areas of East Africa" (Contract no. ERBICIC 18CT 960130).

References

Le Pelly, R.H. 1959. Agricultural insects of East Africa. Nairobi, Kenya: East African High Commission. 307 pp.

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

Reed, W., Lateef, S.S., Sithanantham, S., and Pawar, C.S. 1989. Pigeonpea and chickpea disease identification handbook. Information Bulletin no. 26. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

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.

Minja, E.M. 1997. Insect pests of pigeonpea in Kenya, Malawi, Tanzania, and Uganda; and grain yield losses in Kenya. Consultant's report submitted to the African Development Bank. PO Box 39063, Nairobi, Kenya: ICRISAT.

Night, G. and Ogenga-Latigo, M.W. 1994. Range and occurrence of pigeonpea (*Cajanus cajan)* pests in central Uganda. African Crop Science Journal 2(1): 105-109.

Rubaihayo, P.R., Osiru, D.S.O, and Okware, P. 2000. Performance of pigeonpea in finger millet and sorghum intercrops. African Crop Science Journal 8(1): 49-62.

Cercospora Leafspot in Eastern Africa, and Strategies to Reduce Yield Losses

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Introduction

Pigeonpea is grown in several countries in Africa, the main producers in Eastern and Southern Africa being Kenya, Malawi, Mozambique, Tanzania, and Uganda. Yield-limiting factors include diseases, which cause considerable losses. After wilt, Mycovellosiella leafspot is the most important pigeonpea disease in Eastern Africa, and occurs in all countries in the region. Severity ranges from severe to low (Reddy 1991). The disease is particularly severe in Uganda (Onim and Rubaihayo 1976), Zambia (Kannaiyan and Haciwa 1990), and Kenya (Kimani 1988, Songa 1991).

Mycovellosiella leafspot is known to cause yield losses as high as 75-85%, depending on location and season (Reddy et al. 1993). Combined attacks of Mycovellosiella leafspot and powdery mildew have been reported to cause 32% yield losses in Malawi (Subrahmanyam 1994).

Extensive literature reviews on Mycovellosiella leafspot are available (e.g. Kimani 1996). In Kenya, the disease was first reported by Muller (1950). It is recognized as the most common leafspot of pigeonpea in areas with high rainfall or during wet growing seasons in drier areas (Khan and Rachie 1972, Rubaihayo and Onim 1975, Onim and Rubaihayo 1976, Onim 1980). The disease is widely distributed and causes considerable yield losses. In Kenya, regular occurrence has been reported in farmers' fields and experimental plots in the lower semi-arid areas of Kiambu, Muranga, Embu, and Kitui districts (Kimani 1988, Songa 1991, Songa and King 1994). It occurs in epidemic proportions in high-altitude areas (1200-1700 m) in years when rainfall is heavy and the rainy season extended (Songa et al. 1991). In Malawi the disease is prevalent in all major pigeonpea-growing areas, especially those with high humidity (Subrahmanyam 1994).

Etiology of Mycovellosiella Leafspot

Mycovellosiella leafspot is caused by the fungus *Mycovellosiella cajani* (Henn.) Rangel ex Trotter syn. *Cercospora cajani* (Henn.) = *Vellosiella cajani* (Rangel) (Deighton 1974). Conidia of *M. cajani* isolates attacking pigeonpea in Kenya have been described by Njoya (1991) and Gatheca (2000). Their morphological characteristics are similar to those described by Deighton (1974) for the genus *M. cajani.* The conidia are borne at the tip of the conidiophore, forming chains or acting as conidiophores. Conidia vary considerably in size, ranging from 9-36 µ by 4.5-6 *µ.* The shape is also variable: sub-cylindrical, slightly obclavate-cylindric, straight, rarely curved, or shoe-shaped. Distinct conidial scars are

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observed at the ends. Most conidia are aseptate or have one septum; occasionally conidia with 3-4 septa are observed. Conidiophores appear pale brown, smooth, septate or continuous, straight or slightly flexuous, irregular, cylindrical, and frequently narrowing at the base. There is some variation in conidiophores. Some are short, some are terminal, and others arise as lateral branches of secondary mycelial hyphae. Slight differences in dimensions and shapes observed from those described by Deighton (1974) were attributed to natural variations within the pathogen and environmental conditions.

Culture Requirements

Several workers have reported that *Cercospora* species do not sporulate easily in culture; a medium suitable for one species may not prove satisfactory for another (Goode and Brown 1970, Smith 1971). However, to create artificial epidemics, a quick method for spore production is a prerequisite. Experiments were therefore conducted to establish suitable environmental factors for the growth and sporulation of *Mycovellosiella cajani* in culture (Njoya 1991). Six media were inoculated with a suspension of spores (2 x 10^5 conidia mL^{-1}) from a sponilating colony of *M. cajani.* Numerous colonies occurred on pigeonpea leaf decoction agar (PLDA), and a fair number on carrot leaf decoction agar and potato dextrose agar. There were very few or very small colonies on potato carrot agar, carrot agar, and pigeonpea meal agar. All cultures were more or less similar in morphology, ranging from 1 to 3 mm in diameter (Njoya 1991). Colonies of *M. cajani* appear gray on PLDA (Njoya 1991, Gatheca 2000). *Mycovellosiella cajani* sporulated over a wide rage of pH levels (pH 4-10), but optimally at pH 5. Sporulation occurred in all the three light regimes tested - 24 h dark, 24 h light, and 12/12 h light/dark - but more colonies (higher sporulation) appeared in the plates incubated in a 24 h light regime. Since sporulation occurred in continuous darkness, it appears that no particular wavelength of light is necessary for spore production. *M. cajani* was more fastidious in nutritional requirements for growth than for sporulation. Sporulation occurred in all media, temperature, pH, and light regimes tested so long as there was colony growth. Successive selective subculturing of the sponilating sections of the colonies resulted in cultures with higher sporulation capacity (Njoya 1991).

Host-pathogen relationship

Conidia of *M. cajani* germinated at different rates. Germinated conidia on the leaf surface were first observed 6 h after inoculation of 120-day old plants (pigeonpea cultivar NPP 670) in the glasshouse. Each conidium usually had 1-2 germtubes emerging from the cells. On rare occasions more than two germtubes per conidium were formed. Although most conidia had germinated by the end of the 12 h period, penetration was observed 24 h after inoculation. Germtubes did not form appresoria and penetration was accomplished through the stomata (Njoya 1991).

Gatheca (2000) studied penetration and colonization of *M. cajani* on resistant and susceptible pigeonpea cultivars. She observed differences in spore germination and colonization between resistant and susceptible cultivars. On the susceptible cultivar MKS KO 161/1, spore germination occurred 3 h after inoculation. Germtube growth was rapid, side branches were produced near the stomata and grew directly into the opening. On the resistant cultivar KZ 56, germtube growth was also rapid and extensive but no stomatal ingress was observed. Instead, growing germtubes passed above or beside them. More penetration occurred in the susceptible cultivar 24 h after inoculation. Fifty days after plant inoculation, conidiophores were observed in susceptible and moderately resistant varieties, intertwined to form rope-like structures. No conidiophores were observed in resistant varieties.

Colonization of the plant differed among susceptible and resistant genotypes (Gatheca 2000). *M. cajani* grew rapidly in susceptible cultivars and was observed in adjacent epidermal cells from the site of penetration, deep into the mesophyll and near the epidermis of the leaf within 12 h of inoculation. Cell collapse was seen in the mesophyll directly below the penetration site and in surrounding tissue 24 h after inoculation. In resistant varieties, hyphae are limited to the epidermal cells or a few adjacent cells penetrated first at about 18-24 h after inoculation, after which growth of hyphae apparently ceased. The fungus penetrated the host mostly through the stomata. However, direct penetration was also observed using a transmission electron microscope. Depressions on the cuticle were evident, indicating pathogen ingress into the leaf tissues. Penetration channels were narrower than the hyphae diameter, and fungal ingress was associated with slight wall displacement. Direct penetration of the leaf appears to be through mechanical pressure, as indicated by inward depression of the cell wall at the point of penetration. Results from this study indicate that resistance to *M. cajani* is due to limited conidial germination and limited and delayed sporulation on resistant genotypes (Gatheca 2000).

Symptomatology and plant infection

M. cajani attacks all above-ground plant parts except flowers. Disease symptoms initially appear only on the leaves but later lesions develop on stems, petioles, and pods. On the leaves, the first evidence of the disease is either the appearance of breached irregular spots or dark brown to black spots of less than 1 mm in size on the upper leaf surface. The spots are either numerous or isolated on the leaflets and may or may not have a halo around them. Some of the leaves turn yellow and drop without further enlargement of the spots. Yellowing of leaves is not related to the number of spots.

In some cases the leafspots spread to form a circular lesion 9 mm or more in diameter. The larger spots are dark brown or gray. Some spots have concentric rings while others do not. On the petioles, stems, and pods, the spots are dark and mainly circular or slightly elongated. Later these lesions develop gray centers.

In the field, lower leaves get infected first and infection progresses upward to the top leaves. In some short-statured genotypes such as NPP 670, the disease can progress very rapidly if the outbreak is severe, and all leaves become severely infected. In glasshouse-inoculated plants, leaves are usually equally susceptible regardless of their position. The disease causes severe defoliation both in glasshouse-inoculated plants and in the field. In most cases infected plants drop before turning yellow.

In case of very severe attack, leaves may develop blight symptoms, though this is not very common. The blighted areas first appear as faded green patches that later turn to gray lesions which enlarge rapidly in favorable weather. Blight symptoms were observed at Kabete in the field and in 1- and 2-month old glasshouse-inoculated plants (Kimani et al. 1994).

Epidemiology

Infection by *M. cajani* is favored by prolonged periods of high moisture (Muller 1950, Khan and Rachie 1972, Onim 1980). Serious disease outbreaks occur in seasons when rainfall is high or extended late into the season, or when cloudy conditions persist even after the rains (Songa 1991). Conidia germinate at temperatures of 15-30°C (Njoya 1991). In culture (pigeonpea leaf decoction agar), growth and sporulation was best at 10 days of incubation; the optimum conditions for incubation are temperature 20-25°C, 24 h light regime, and pH 5 (Njoya 1991).

Screening Techniques

Two methods have been used in Eastern Africa to screen for leaf spot resistance:

- Field screening under natural epidemics
- Artificial inoculation followed by screening in the glasshouse and in the field.

Screening under natural epidemics

This procedure was first used in Makerere University, Uganda, during 1971-75 (Onim and Rubaihayo 1976). A total of 2107 cultivars were planted in single rows. Disease reaction was scored 60 days after planting, and 134 single plants (early-maturing, resistant plants with good yield potential) were selected at the pod-filling stage. Eleven lines from these selections were evaluated at five locations in Uganda and Kenya. Disease reaction in the progeny rows was assessed by randomly plucking 18 leaflets of approximately the same age (1 leaflet per plant) from the main stem, halfway up the plant, and counting the number of leafspots on each leaflet. All 11 lines were attacked by Mycovellosiella leafspot at all locations. However, four lines (UC 796/1, 251/2, 2113/1, and 2568/1) showed promise, with a combination of resistance and high grain yield. The marked difference in disease level and grain yield observed between locations was closely associated with the amount and duration of rainfall, with the disease being severe in wet areas.

Other workers have also evaluated pigeonpea lines for resistance (Songa 1991, Njoya et al. 1991, Gatheca 2000). Songa (1991) evaluated 197 lines at Katumani, Kenya after a serious outbreak of the disease in all pigeonpea fields around the station. The rapid spread of the disease was attributed to high rainfall that extended late into the season, and cold cloudy conditions that persisted even after the rains. A 9-class scoring scale was used, 1 = highest level of resistance, 9 = extreme susceptibility. Most lines succumbed to the disease and none could be considered highly resistant (the best score was 4). However, 15 lines with low to very low resistance were selected for further evaluation at different locations and seasons.

Njoya et al. (1991) also reported that out of 101 lines evaluated at Katumani, 13 lines were found to be resistant, 20 moderately resistant, and 33 tolerant. Of the 60 lines evaluated at Kiboko, 8 lines were resistant, 8 moderately resistant, and 13 lines tolerant. It was observed that in early-maturing cultivars, susceptibility increased with physiological age after flowering - at the pod-filling stage all five lines tested showed high susceptibility. In contrast, in late-maturing cultivars susceptibility did not seem to depend on the stage of plant growth. The two late-maturing cultivars used in the inoculated experiments showed high susceptibility although they were still in the vegetative growth stage. So long as there was enough inoculum and environmental conditions in the field were favorable, the late-maturing cultivars were severely affected. It thus appears that early-maturing cultivars should be scored at mid-pod filling in order to avoid erroneous ratings due to delayed onset and development of the disease (Njoya et al. 1991). Thus, a standardized rating scale should include the age at which pigeonpea germplasm should be evaluated for leafspot resistance.

Artificial inoculation under controlled environment and field screening

Numerous resistance screening techniques have been developed for other crops under controlled conditions. The advantage of controlled environments is that screening can usually be done throughout the year, and the process is relatively quick. A technique for screening pigeonpea germplasm for *M. cajani* resistance was evaluated in the glasshouse in Kabete (Njoya 1991). Inoculum was prepared by pipetting 1mL of conidial suspension (2 x 10^5 conidia mL^{-1}) and spreading it evenly onto plates of host leaf decoction agar medium. The plates were incubated at 20°C for-14 days. At the end of the incubation period 20 mL of sterile distilled water was added to each culture plate and conidia were detached by gently rubbing the culture surface with the sterile edge of a microscope slide. Inoculation in the glasshouse and in the field was accomplished by spraying pigeonpea plants with conidial suspension (2 x 10^6conidia mL^{-1}). Inoculation was repeated after 48 h. High humidity was maintained after inoculation by covering the plants with polythene bags for 48 h in the glasshouse. At the time of inoculation it was raining at Kiboko and Kabete, and conditions were favourable for infection. There was also a lot of natural infection in the fields.

Njoya (1991) found no correlation in leafspot severity between germplasm inoculated when 2 weeks old, and those infected in the field at Kabete and Kiboko. However, Gatheca (2000) inoculated germplasm in the glasshouse at the flowering stage. She evaluated 50 pigeonpea lines at Kabete, Katumani, and in the glasshouse, and found a positive correlation between field and glasshouse ratings for reaction of pigeonpea germplasm to *M. cajani.*

Control of Mycovellosiella Leafspot

There is little information available on control of this disease. This is possibly due to the fact that until recently it was not considered serious and relatively little work was done on many aspects. Experiments conducted in Eastern Africa indicate that it can be controlled either by use of chemicals or by growing resistant cultivars.

Chemical control

Onim (1980) evaluated five foliar fungicides for control of Mycovellosiella leafspot in Uganda - Karathane (i.e. 25% karathane), Dithane M-45 (80% mancozeb), Bavistin (50% carbendazim), Benlate (50% benomyl) and Captan (50% captan). Benlate and Bavistin caused slight stunting of plants and depressed grain yield possibly due to their phytotoxic effects. Karathane also was ineffective in controlling leafspot. Dithane M-45 was the most effective. It significantly reduced leaf fall and increased grain yield. However, there were no significant differences in grain yield at spraying intervals of 7,14, and 21 days during the 5-month study. Plant growth was most luxurious on plots sprayed with Dithane M-45. With Benlate, all spraying intervals significantly reduced leaf-fall, but leaf fall was highest when spraying was done at 7-day intervals, perhaps due to phytotoxic effects. It was concluded that spraying intervals in the range of 7-21 days for Dithane and 14-21 days for Benlate would be beneficial. It was also shown that spraying with Dithane gave 85% more grain yield than the unsprayed control. Onim (1980) concluded that although Benlate and Dithane are effective, their application for the management of leafspot may not be economical.

Use of resistant cultivars

Use of resistant pigeonpea cultivars should provide the most practical, economical, and long-lasting management strategy. Selection for resistance to *Mycovellosiella cajani* in the field and in the glasshouse has been reported by several workers (Onim and Rubaihayo 1976, Rodriguez and Melendez 1984, Songa 1991, Kimani et al. 1994, Gatheca 2000). Khan and Rachie (1972) and also Onim and Rubaihayo (1976) have reported wide variation in resistance among pigeonpea lines, suggesting that resistance to *M. cajani* may be polygenic. The number of genes conferring resistance may vary among cultivars, being higher in resistant cultivars. A few sources of resistance have been identified, including UC 2515/2,769/1, and 2113/1 from Uganda (Onim and Rubaihayo 1976) and ICP 8869,12792, and 12165 from Zambia (Kannaiyan and Haciwa 1990). Several resistant lines have been identified in Kenya (Songa 1991, Njoya et al. 1991, Gatheca 2000). Songa (1991) identified resistant genotypes belonging to different maturity groups: KCC 50/3, 60/8, 119/6, and 1423/13 (short duration); KCC 81/3/1, 576/3, 657/1,777 and ICP 13081 (medium duration); and KCC 66, 605, 666, and ALPL 6-2 (long duration). Lines KO 174/7 and KB 43 were found to be resistant to *M. cajani* at Machakos (Njoya 1991). Gatheca found a high positive correlation for resistance to *M. cajani* in greenhouse and field inoculated plants. She found lines KZ 56, KO 31, ICPL 93015, and ICPL 87091 to be resistant in the greenhouse and in the field both at Kabete and Katumani.

References

Deighton, F.C. 1974. Studies on *Cercospora* and allied genera: *Mycovellosiella* Rangel and new species *Ramulariopsis.* Mycological Papers no. 137:3-6.

Gatheca, F.M. 2000. Screening for resistance to Mycovellosiella leafspot and assessment of the extent of hyphal colonization and sporulation of *Mycovellosiella cajani* in pigeonpea lines. MSc thesis, University of Nairobi, Kenya.

Goode, M.J. and Brown, C.R. 1970. Detection and characterization of *Cercospora citrullina* isolates that sporulate readily in culture. Phytopathology 60:1503-1508.

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.

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

Khan, T.N. and Rachie, K.O. 1972. Preliminary evaluation and utilization of pigeonpea germplasm in Uganda. East African Agriculture and Forestry Journal 38:78-82.

Kimani, P.M. (ed) 1996. Leafspot, *Mycovellosiella cajani.* Pages 129-310 *in* Pigeonpea monograph. Nairobi, Kenya: University of Nairobi.

Kimani, P.M. 1988. The second report of pigeonpea project (Kenya), Phase IV. Ottawa, Canada: International Development Research Centre.

Kimani, E.W., Kimani, P.M., and Mwangombe, A.W. 1994. Symptoms and reaction of eight pigeonpea genotypes to *Mycovellosiella cajani.* Pages 82-94 *in* Proceedings of the 4th KARI Annual Scientific Conference, 5-7 Sep 1994, Nairobi, Kenya. Nairobi, Kenya: Kenya Agricultural Research Institute.

Muller, A.S. 1950. Preliminary survey of plant disease in Guatemala. Plant Disease Reporter. 34:203-207.

Nevill, D.J. and Evans, A.M. 1980. The effect of host development on the field assessment of disease resistance to Cercospora leafspots in groundnuts, *Arachis hypogaea* L. Journal of Agricultural Sciences 94:229-237.

Njoya, E.W. 1991. Studies on pigeonpea leafspot etiology and the effect of plant age and leaf position. MSc thesis, University of Nairobi, Kenya.

Njoya, E.W., Kimani, P.M., Mwangombe, A.W., and Shankar, M. 1991. Reaction of pigeonpea genotypes to a leafspot 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., Ariyanayagan, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Onim, J.F.M. 1980. Foliar fungicides for the control of *Mycovellosiella cajani* causing leafspot 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(2): 121-125.

Reddy, M.V. 1991. 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 June 1990, Nairobi, Kenya. PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Reddy, M.V., Raju, T.N., Sharma, S.B., Nene, Y.L., and MacDonald, D. 1993. Handbook of pigeonpea diseases. Information Bulletin no. 42. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Rodriguez, R. and Melendez, P.L. 1984. Field screening of pigeonpea *Cajanus cajan* for resistance to foliar diseases in Puerto Rico. Journal of Agricultural Research Unit of Puerto Rico 68(3):275-279.

Rubaihayo, P.R. and Onim, J.F.M. 1975. A study of some characters of pigeonpea. Sabrao Journal 7(2): 183-187.

Smith, D.H. 1971. A simple method for producing *Cercospora arachidicola* conidial inoculum. Phytopathology 61:1414.

Songa, W.A. 1991. 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., Ariyanayagan, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

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.

Songa, W. and King, S.B. 1994. Pigeonpea pathology research in Kenya: progress and future research strategies. Pages 45-50 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, Bulawayo, Zimbabwe, 25-27 Oct 1993 (Silim, S.N., Tuwafe, S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Subrahmanyam, P. 1994. Pigeonpea diseases in eastern and southern Africa. Pages 32-36 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, Bulawayo, Zimbabwe, 25-27 Oct 1993 (Silim, S.N, Tuwafe, S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Discussions - Crop Protection

Fusarium wilt resistance

The study on the genetics of wilt resistance has a number of implications for future research. There are two scenarios to consider:

- Digenic inheritance in two cases (9:7 and 13:3) - it is possible to fix this type of inheritance and transfer it to susceptible genotypes using modified backcrossing procedures.
- The third set of crosses suggests some form of quantitative inheritance (although with di-hybrid segregation). It appears that it is additive. This implies the possibility of selecting for increasing the number of desirable alleles or combinations in a population.

Marker-assisted studies can help accelerate progress in breeding for resistance. However, use of markers will be possible only after we have at least a rough understanding of the pigeonpea gene map, and the location of Quantitative Trait Loci (QTLs). This knowledge is not currently available. There is an urgent need for gene mapping studies, particularly because wilt resistance is controlled by multiple genes, the QTLs for which may be scattered in different parts of the map.

Insect pests

Several pests are important, but the critical issue, particularly for short-duration pigeonpea, is insect pests. Some pests like flower beetles or thrips are sporadic, but can cause 100% loss in some years. Others like the pod borer *Maruca* cause smaller losses but occur almost every year. The relative importance of different pest species varies considerably between areas, even within the same country. Information on threshold levels and optimal spray regimes is lacking some countries.

Effect of intercropping

Some presentations noted that pod borer populations were high in a maize/pigeonpea intercrop. One factor could be the shade and micro-environment provided by the tall maize plants. This encourages pod borers to stay within the intercrop, causing them to feed on pigeonpea for longer periods.

Botanical control methods

Tephrosia has given good results in several studies, and could be promoted more widely. The active ingredient is rotenone, which can act as a contact poison (when it touches the skin of the target pest) or through ingestion. Neem is another possibility. Considerable information is available on neem from studies in India. It has not proved cost-effective in

India, but could be tried under African conditions. However, presentations at the meeting noted that expensive, factory-prepared neem extract was not much more effective than a crude formulation of Tephrosia, which presumably contained limited quantities of active ingredient. Neem is likely to be useful only in high-value crops. Tephrosia may be cheaper even though large quantities must be prepared - however, labor constraints could be a problem in collecting and crushing the leaves.

Farmer interest in Tephrosia has been encouraging. The shrub can provide multiple benefits - green manure and large improvements in soil fertility, acting as a wind-break, etc. In parts of Eastern Africa it is traditionally planted on field borders to control moles, which eat the roots and are poisoned. However, more information is needed on residual effects and cost-effectiveness.

Strategic versus applied research

There are still gaps in our knowledge of pest control. For example, does damage increase the susceptibility of a pod to attack by other pests? What pests occupy what niches in the cropping system? Will different pests attack the same pod? These questions can only be answered by detailed studies. Most important is the need for more research on natural enemies.

Comparative advantages must be identified and exploited. For example, academic institutes (e.g. universities) have the advantage in strategic research and detailed studies; ICRISAT could focus on broad control measures and on the economics of implementation; NGOs could help stimulate adoption. With multiple partners involved, we should aim to maximize synergy in order to develop cost-effective control methods and stimulate adoption.

Chemical control

Endosulphan and dimethoate are widely available and generally effective. In contrast, synthetic pyrethroids are broad-spectrum contact poisons that kill non-target organisms, even spiders and small lizards. They should be used only when pest populations increase to unmanageable levels and cannot be controlled with less powerful insecticides. There may be need to identify (i) specific active ingredients that work against high population levels of a single pest, with minimal non-target damage, (ii) cheap chemicals that will control a wide range of pests at low or moderate populations.

General approach

In general, farmers lack sufficient understanding of pest control methods and especially of threshold levels. We must focus on educating farmers about pest control. For such a campaign to be effective, farmers must be given simple instructions, e.g. "When you see Lampides eggs in large numbers, a severe pest attack is imminent.'' We must focus on 2-3 insecticides that are easily available, cheap, and easy to use. Information can also be disseminated through Farmer Field Schools. In parallel, detailed research can continue; but we must aim to disseminate available technology. Studies have shown that available technology packages for pest control offer benefit:cost ratios of above 1.5, and are thus suitable for promotion.

Crop Management

Improved Management Practices to Increase Productivity of Traditional Cereal/Pigeonpea Intercropping Systems in Eastern Africa

G Mergeai[1], S N Silim[2], and J P Baudoin[1]

Introduction

Among the traditional cropping systems involving pigeonpea in Eastern and Southern Africa, the pigeonpea/cereal intercrop is the most common. The cereal (maize, sorghum, finger millet in different regions) is generally the main crop. Pigeonpea is regarded as a "bonus" crop and an insurance against total crop loss due to poor rainfall. Management practices are orientated to maximize the cereal yield. In most regions, planting is generally done in rows at fairly low density (30 000 to 60 000 plants ha^{-1} for maize or sorghum and about 10 000 plants ha^{-1} for pigeonpea), one row of pigeonpea alternating with several (from 2 to 10) rows of cereal (Le Roi 1997). In Uganda, long- and medium-duration pigeonpea landraces are generally broadcast with finger millet (Silim et al. 1995). Traditional pigeonpea cultivars take from 6 to 10 months to mature and are well suited to this cropping system because they grow very slowly at the beginning of their cycle, flowering only after the main crop is harvested, and providing very little competition for light, water, or nutrients (Sivakumar and Virmani 1980).

Improved long-, medium-, and short-duration pigeonpea cultivars developed during the last 15 years by the University of Nairobi, Kenya Agricultural Research Institute (KARI), and ICRISAT are becoming increasingly popular with farmers (Le Roi 1997). Due to their much shorter vegetative cycle (4-5 months) and their smaller growth habit, short- and medium-duration varieties are much more sensitive to competition from the companion crop than long-duration varieties and, therefore, are not normally suitable for intercropping with tall cereals. Moreover, they are very sensitive to insect pests because their reproductive stage coincides with the seasonal peaks in insect populations. The crop can be completely destroyed if no pest control is done. In spite of these constraints, a large proportion of East African farmers who receive seed of short-duration pigeonpea varieties, intercrop with maize or sorghum as they do with their long-duration landraces. A series of experiments have been conducted in the region in recent years to improve the productivity of cereal/ pigeonpea intercropping systems by modifying the spatial arrangement and plant population of the components crops. In this paper, we review the results obtained from these experiments, identify areas where complementary investigations are needed, and discuss constraints to the adoption of improved cropping systems.

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Improved Management Practices for Traditional Intercropping Systems

Before making a recommendation on improved management practices, numerous factors must be taken into consideration - the intercrop components and their compatibility, environmental conditions, possible spatial arrangements, planting sequences, plant populations, productivity, and farmers' preferences. The large number of these factors, and possible interactions amongst them, make it difficult to formulate precise recommendations (Willey 1979). After gaining an understanding of these factors in a given farming system, the next stage is to define the best spatial arrangement, planting sequence, and plant populations of the different components so as to minimize competition (Ali 1990). The less complicated and less risky a new management practice, the higher the probability that it will be adopted by smallholder farmers.

In most traditional cereal/pigeonpea intercropping systems, pigeonpea single rows alternate with several rows of tall cereal (maize or sorghum). Both components are planted simultaneously at the beginning of the most reliable rainy season. After harvest of the cereal, pigeonpea plants are left in the field to finish their growth cycle during the second and less reliable annual rainy season. Due to their low plant population (about 10 000 plants ha^{-1} on average) they usually produce low yields, varying between 300 and 700 kg ha^{-1} (Le Roi 1997).

In order to identify a spatial arrangement that would significantly improve pigeonpea yield without greatly affecting productivity of the cereal component, six arrangements were compared on-station by ICRISAT at two sites in 1993/94. Traditional and improved long-duration pigeonpea varieties were intercropped with maize (data not shown). The best results were obtained with a paired row of pigeonpea alternating with three rows of maize. In paired rows, two pigeonpea rows are sown without an intervening cereal row, and spaced 40-50 cm apart. By contrast, in the traditional intercropping system all rows, whether maize or pigeonpea, are equally spaced 80-100 cm apart.

The most common traditional intercropping system is 3 cereal rows + 1 pigeonpea row. In the paired row arrangement, pigeonpea occupies an area almost similar to that in the traditional arrangement, but pigeonpea plant population is doubled. Thus, this arrangement can better exploit the space left after the cereal harvest.

The paired-row system was tested on-farm for 2 years, 1994/95 and 1995/96, at six sites in eastern Kenya with a total of 25 farmers. The farmers compared traditional versus improved management practices on their landraces and on an improved long-duration variety Kat 81/3/3.

Improved management: one paired row of pigeonpea intercropped with three rows of maize. Distance between pigeonpea rows 50-60 cm depending on soil moisture availability. Distance between maize rows 80 cm. *Traditional management:* one single row of pigeonpea intercropped with 3 to 5 rows of maize with a constant distance of 80-100 cm between rows.

Both components of the intercropping system were planted at the same time using an ox-drawn moldboard plow. Using the improved practice, farmers achieved on average over 50% increase in pigeonpea yield - with no decline in maize production and no extra labor

Table 1. Comparison of traditional versus improved intercropping systems, involving maize and long-duration pigeonpea.

	Maize yield ($kg ha^{-1}$)	Pigeonpea yield ($kg ha^{-1}$)
Traditional practice		
Traditional pigeonpea varieties	1459	1091
Improved long-duration pigeonpea Kat 81/3/3	1231	811
Improved practice		
Traditional pigeonpea varieties	1539	1497
Improved long-duration pigeonpea Kat 81/3/3	1252	1460
Average gains from improved practice (%)		
Traditional pigeonpea varieties	5.48	37.21
Improved long-duration pigeonpea Kat 81/3/3	1.71	80.02

Improved system = paired pigeonpea rows alternating with maize
Data pooled from 25 farmers across 5 sites in eastern Kenya

cost (Table 1). Interestingly, the pigeonpea landrace gave higher yields than the improved long-duration variety, which was bred for sole cropping at higher altitudes. With its bushy habit, the improved long-duration variety competed too strongly with maize. When breeding long-duration pigeonpea for intercropping systems, it is thus advisable to look for compact genotypes with a rather low competitive ability.

Improved Management Practices for New Intercropping Systems

Most farmers who receive seed of improved short- and medium-duration pigeonpea tend to grow them in intercrop systems, the same way they do with their traditional varieties. Therefore, it was important to identify suitable systems where the new varieties could be intercropped with maize, sorghum, or finger millet. Different spatial arrangements and plant populations were tested for these intercropping systems in several experiments in Kenya and Uganda. A summary of the main results is presented below.

Maize/short-duration pigeonpea intercropping systems

In Kenya, ICRISAT carried out a preliminary trial in 1995 at Kiboko research station (altitude 900 m) in order to determine optimal plant density and spatial arrangement. Short-duration pigeonpea ICPL 87091 was intercropped with maize (Katumani hybrid) using various arrangements. These included sole crops, intercrops consisting of nonpaired rows at different row ratios (1:1,1:2,2:4,2:2 and 2:1), and intercrops with paired rows. In the latter, maize rows were paired, and intercropped with 1, 2, or 3 rows of pigeonpea; and all rows were spaced at 40 cm.

In the sole crops, spacing was 80 x 30 cm for maize and 40 x 10 cm for pigeonpea. In all systems, the distance between maize and pigeonpea rows was kept constant at 40 cm. Table 2 shows the results of this experiment. All intercrops gave LERs above 1, but in general better results were obtained from treatments involving paired maize rows. The best system appeared to be paired rows of maize alternating with 2 rows of pigeonpea. This arrangement gave the second highest LER of 1.30, and also gave high maize yields.

Another trial was conducted at Thika research station (altitude 1580 m), Kenya, by Gembloux Agricultural University, during the long rainy season (Mar-June) of 1999. In this experiment, 2:2 rows were planted at different intra-row spacings, with inter-row spacing kept constant at 60 cm. No paired rows were used. Two pigeonpea varieties, Kat 60/8 and ICPL 87091, were tested. The results were disappointing. Pigeonpea plants were stunted due to the low temperature and high maize plant population, and pigeonpea yields were low. Consequently, although maize yields were high (5.9 t ha^{-1} in sole crop, and >4 t ha^{-1} in many intercrop treatments), the total LER of the intercrop treatments was low, either below or marginally above 1.

Sorghum/short-duration pigeonpea intercropping

Several experiments were carried out in Uganda by Makerere University and Gembloux Agricultural University in order to develop improved sorghum/short-duration pigeonpea intercropping systems. We used the same approach as described above for maize/ pigeonpea. First, trials were conducted at Kabanyolo to compare various row arrangements. Then a second trial was conducted at Serere, using only the best row arrangement, to study the effects of inter-row spacing and plant population.

Two intercropping trials were carried out at Kabanyolo (altitude 1200 m) during two consecutive rainy seasons - planted in Aug 1997 and Feb 1998. The treatments included sole crops, and intercrops consisting of nonpaired rows at different row ratios (1:1,2:1,2:2). Inter-row spacing was kept constant at 60 cm. Intra-row spacing was also kept constant in all treatments, except that for sorghum, it was reduced from 20 cm to 15 cm between sole and intercrop situations. The varieties used were sorghum Seredo, and pigeonpea Kat 60/8 and ICPL 87091. Results are shown in Table 3. The best results, with a remarkably high LER of 1.47, came from a 2:2: row arrangement of Seredo and Kat 60/8.

Another trial was conducted at the Serere Agricultural and Animal Research Institute (altitude 1100 m) by Gembloux Agricultural University, in the long rainy season of 1999, i.e. planted in March 1999. In this experiment, 2:2 rows were planted at different intra-row spacings, with inter-row spacing kept constant at 60 cm. No paired rows were used. The same three varieties were tested - sorghum Seredo, pigeonpea varieties Kat 60/8 and ICPL 87091. The results were not convincing. Due to lush growth in sorghum, pigeonpea was suppressed: pigeonpea yields ranged from 331 to 536 kg ha^{-1}, and pigeonpea LERs from 0.26 to 0.58. Total LERs in all intercrops were below 1, with the exception of one treatment with Seredo-Kat 60/8, which gave an LER of 1.08.

Finger millet/short-duration pigeonpea intercropping

Intercropping trials involving finger millet and short-duration pigeonpea were carried out in Uganda by Makerere and Gembloux Universities from early 1999 to early 2000. As in the other experiments, the first step aimed at identifying the optimal spatial arrangement under different plant populations of both components.

A trial was planted at two sites (Kabanyolo and Ngetta, altitude 1100 m) in two consecutive seasons, i.e. planted in Mar and Aug 99. The early to medium-duration pigeonpea cultivar Kat 60/8 was intercropped with finger millet variety Pese 1, at various row ratios and plant populations. Paired rows were not used. The treatments included two row ratios (millet:pigeonpea 2:2: and 4:1) and four levels of plant population. Sole crops were also tested. Inter-row spacing was 30 cm between finger millet rows, 60 cm between pigeonpea rows, and 45 cm between millet and pigeonpea rows.

Results are shown in Table 4, averaged across the four trials. Again, the 2:2 row ratio gave the best results.

The superiority of 2:2 for short-duration pigeonpea was confirmed in another trial where improved short-duration ICPL 87091 and early to medium-duration Kat 60/8 were intercropped with finger millet Pese 1. Millet:pigeonpea row ratios of 2:2, 2:1, and 4:1 were tested, along with broadcasting, which is a common farmer practise. This trial was conducted thrice-twice at Kabanyolo, planted in Feb and Aug 1999; and once at Ngetta, planted in Mar 1999. Table 5 shows the results averaged across the three trials. As in the previous experiment, the inter-row spacing was 30 cm between finger millet rows, 60 cm between pigeonpea rows, and 45 cm between millet and pigeonpea rows. The results confirmed that for both pigeonpea varieties, the 2:2 row ratio gave the best yields.

Discussion and Conclusions

The experiments tested three types of intercropping - tall cereal (maize or sorghum) with long-duration pigeonpea, tall cereal with short-duration pigeonpea, and short cereal (finger millet) with short-duration pigeonpea. The results clearly showed that maize/long-duration pigeonpea and finger millet/short-duration pigeonpea systems are beneficial. With tall cereals/short-duration pigeonpea, the benefit is much less evident.

The arrangement with paired rows of medium- or long-duration pigeonpea alternating with three unpaired rows of maize drastically increased productivity. This is only a minor modification of traditional farmer practice, does not present major risks, and is well suited to the current situation, where most farmers regard pigeonpea as a food-security crop. Considering the simplicity of this new planting technique, which is within the capabilities of every small farmer, one can assume that dissemination should not be too difficult. Ideally, an evaluation of adoption near the six sites where paired rows were introduced in 1995 should be conducted before starting dissemination on a large scale.

Intercropping short- and early-medium duration pigeonpea with finger millet using a 2:2 row ratio can increase productivity by nearly 30% when the right plant populations of both components are used. However, effective pest control is an essential prerequisite. In addition, adoption of this system would be complicated in the traditional finger millet/ pigeonpea areas, mainly located in northern Uganda, because it is totally different from current smallholder practice, which is to broadcast both crops. Moreover, considering the susceptibility of determinate short-duration pigeonpea varieties to insect pests, it is

Table 2. Identification of the best spatial arrangement for intercropping maize with short-duration pigeonpea, Kiboko, Kenya.

	Density (plants ha^{-1})		Yield (kg ha^{-1})		LER		
	Maize	Pigeonpea	Maize	Pigeonpea	Maize	Pigeonpea	Total
Sole maize (M) 80 cm inter-row spacing	41 667	–	3567	–	1.00		1.00
Sole short-duration pigeonpea (PP) ICPL 87091 - 40 cm spacing	–	250 000	–	3044		1.00	1.00
Intercrop M and PP, 1:1 ratio	41 667	125 000	2811	1306	0.79	0.43	1.22
Intercrop M and PP, 1:2 ratio	27 778	166 667	2856	1583	0.80	0.52	1.32
Intercrop M and PP, 2:4 ratio	17 857	142 857	2222	1472	0.62	0.48	1.10
Intercrop M and PP, 2:2 ratio	25 000	100 000	2756	1100	0.77	0.36	1.13
Intercrop M and PP, 2:1 ratio	31 250	62 500	3300	844	0.93	0.28	1.21
Intercrop paired rows M (40 cm spacing) and 1 row PP (40 cm spacing)	55 556	83 333	3422	789	0.96	0.26	1.22
Intercrop paired rows M (40 cm spacing) and 2 rows PP (40 cm spacing)	41 667	125 000	3033	1378	0.85	0.45	1.30
Intercrop paired rows M (40 cm spacing) and 3 rows PP (40 cm spacing)	33 333	150 000	2333	1756	0.65	0.58	1.23

Table 3. Identification of the best spatial arrangement for intercropping sorghum with short-duration pigeonpea, Kabanyolo, Uganda.

	Density (plants ha^{-1})		Yield (kg ha^{-1})		LER		
	Sorghum	Pigeonpea	Sorghum	Pigeonpea	Sorghum	Pigeonpea	Total
Sole sorghum variety Seredo (S)	83 333		3211.5		1.00		1.00
Sole short-duration pigeonpea ICPL 87091 (PP1)		83 333		1019.5		1.00	1.00
Sole early to medium-duration pigeonpea Kat 60/8 (PP2)		55 556		1118.5		1.00	1.00
Intercrop S-PP1, 1:1 ratio	55 556	41 667	1669.5	366	0.52	0.36	0.88
Intercrop S-PP1, 2:1 ratio	74 074	27 778	2584.5	467	0.80	0.46	1.26
Intercrop S-PP1, 2:2 ratio	55 556	41 667	2786	691	0.87	0.68	1.55
Intercrop S-PP2, 1:1 ratio	55 556	27 778	1859.5	383	0.58	0.34	0.92
Intercrop S-PP2, 2:1 ratio	74 074	18 519	2584.5	410.5	0.80	0.37	1.17
Intercrop S-PP2, 2:2 ratio	55 556	27 778	2885	641.5	0.90	0.57	1.47

Table 4. Determination of optimal spatial arrangement and plant populations for intercropping finger millet with short-duration pigeonpea, Kabanyolo and Ngetta, Uganda.

	Density (plants ha^{-1})		Yield (kg ha^{-1})		LER		
	Millet	Pigeonpea	Millet	Pigeonpea	Millet	Pigeonpea	Total
Intercrop finger millet: pigeonpea,	55 556	28 778	555	780	0.35	0.72	1.07
2:2 row ratio, at various plant populations	74 074	37 037	674	800	0.43	0.74	1.17
	111 111	55 556	648	830	0.41	0.76	1.17
	222 222	111 111	478	629	0.31	0.58	0.89
Intercrop finger millet: pigeonpea,	55 556	13 889	1054	385	0.67	0.35	1.02
4:1 row ratio, at various plant populations	74 074	18 519	1182	429	0.75	0.39	1.14
	111 111	27 778	1171	479	0.75	0.44	1.19
	222 222	55 556	886	345	0.57	0.32	0.89
Sole pigeonpea at various plant populations		41 667		978		1.00	1.00
		55 556		1086			
		83 333		1026			
		166 667		771			
Sole finger millet at various plant populations	166 667		1379		1.00		1.00
	222 222		1566				
	333 333		1449				
	666 667		1085				

Finger millet variety Pese 1, pigeonpea variety Kat 60/8

Table 5. Determination of optimal spatial arrangement and plant populations for intercropping finger millet with short-duration pigeonpea, Kabanyolo and Ngetta, Uganda.

	Density (plants ha^{-1})		Yield (kg ha^{-1})		LER		
	Millet	Pigeonpea	Millet	Pigeonpea	Millet	Pigeonpea	Total
Pigeonpea variety Kat 60/8							
Intercrop millet: pigeonpea, 2:2 row ratio	111 111	37 037	809	973	0.41	0.87	1.28
Intercrop millet: pigeonpea, 2:1 row ratio	166 667	27 778	1060	607	0.54	0.54	1.08
Intercrop millet: pigeonpea, 4:1 row ratio	222 222	18 519	1520	451	0.78	0.40	1.18
Intercrop millet: pigeonpea, both crops broadcast	166 700	27 800	839	459	0.43	0.41	0.84
Sole pigeonpea		55 556		1121		1.00	1.00
Pigeonpea variety ICPL 87091							
Intercrop millet: pigeonpea, 2:2 row ratio	111 111	55 556	916	691	0.47	0.83	1.30
Intercrop millet: pigeonpea, 2:1 row ratio	166 667	41 667	1145	428	0.59	0.51	1.10
Intercrop millet: pigeonpea, 4:1 row ratio	222 222	27 778	1480	252	0.76	0.30	1.06
Intercrop millet: pigeonpea, both crops broadcast	166 700	41 700	988	407	0.50	0.49	0.99
Sole pigeonpea		83 333		834		1.00	1.00
Sole finger millet	333 333		1957		1.00		1.00

Finger millet variety Pese 1, pigeonpea varieties Kat 60/8 and ICPL 87091 advisable to use indeterminate short-duration pigeonpea in this type of intercropping system. The 2:2 arrangement needs to be tested further under on-farm conditions before dissemination.

Contradictory results were obtained regarding the intercropping of short- and early to medium-duration pigeonpea with tall cereals (maize or sorghum). Some trials showed interesting productivity gains in intercrops compared to sole crops, while others showed no LER advantage under intercropping. Among the various spatial arrangements tested, two arrangements often gave good results - paired rows of maize alternating with 2 rows of pigeonpea, and 2:2 row ratio of (unpaired) maize and pigeonpea.

In this study, paired-row sowing was used as a way to improve the traditional intercropping system which involves long-duration pigeonpea. However, paired-row sowing is usually used to reduce competition from dominant tall crops against the dwarf component crop in an intercrop (Ali 1990). Moreover, it is thought that increased intra-specific root competition induced by paired rows leads to reduced root growth and slower depletion of soil moisture in the early stages of the crop vegetative cycle, which in turn leads to more water availability during the grain-filling stage (Rowland and Whiteman 1993). In semi-arid conditions, Blum and Naveh (1976) observed that alternate paired-rows of sole sorghum (planted 40 cm apart with 160 cm between row pairs) produced significantly greater yields than single rows (planted 100 cm apart) in 50% of years, and similar yields in the other 50%. As yield was increased in the dry years with the same evapotranspiration, they concluded that competition in the paired-row system improved water-use efficiency.

Acknowledgments

The authors gratefully acknowledge the financial support they received from the African Development Bank-funded project "Improvement of pigeonpea in Eastern and Southern Africa" and from the European Union-funded project no. ERBICIC 18 CT 96130, "Genetic improvement of pigeonpea and management of intercropping systems in semi-arid areas of East Africa" to carry out the research work reported in this paper.

References

Ali, M. 1990. Pigeonpea cropping systems. Pages 279-301 *in* The pigeonpea (Nene, Y.L., Hall, *S.D.,* and Sheila, V.K., eds). Wallingford, Oxon, UK: CAB International.

Blum, A. and Naveh, M. 1976. Improved water-use efficiency in dryland grain sorghum promoted by plant competition. Agronomy Journal 68:111-116.

Le Roi, A. 1997. MSc thesis, Faculte Universitaire des Sciences agronomiques de Gembloux, Belgium. 75 pp.

Rowland, J. and Whiteman, P. 1993. Principles of dryland farming. Pages 68-94 *in* Dryland farming in Africa (Rowland, J.R.J., ed). London, UK: Macmillan Press.

Silim, N.M., Musaana, M.S., Ugen, M.A., and Areeke, T.E.E. 1995. Survey of pigeonpea production and post-production systems in three districts of Uganda. Pages 67-73 *in*

Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Bulawayo, Zimbabwe (Silim, S.N., Tuwafe S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Sivakumar, M.V.K. and Virmani, S.M. 1980. Growth and resource use of maize, pigeonpea and maize/pigeonpea intercrop in an operational research watershed. Experimental Agriculture 16:377-386.

Willey R.W. 1979. Intercropping, its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abstracts 32:1-10.

Cereal-Pigeonpea Intercropping Systems: the Ugandan Experience

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Introduction

Pigeonpea is an important grain legume in Uganda. It is consumed mostly as dry grain, but fresh green peas are also eaten as vegetables. The grain and fodder are excellent livestock feed, especially during the dry season. Stems are used for fencing, baskets, and construction materials for huts, and in the more arid regions, as fuelwood. Pigeonpea usually improves soil fertility through nitrogen fixation and its ability to recycle nutrients through its deep rooting system.

The total area under pigeonpea cultivation in Uganda is estimated at 72,000 ha (Saxena 1999). Production is concentrated mostly in the drier northeastern and northern areas (Apac, Lira, Gulu, Kitgum, Soroti, Kumi, Arua, Moroto). Production in the wetter parts of the country is probably limited by the prevalence of cercospora leafspot disease and competition from other grain legumes.

Pigeonpea is largely grown in association with other crops, usually cereals. In north and northeastern Uganda it is intercropped with finger millet, which is considered as the main crop - the pigeonpea yield is regarded as a bonus (Silim et al. 1991). Medium- and long-duration landraces or cultivars, especially Apio Elena and Adong, are the most favored because they mature much after the other component crops, ensuring that the peak growth demands of the component crops occur at different times, giving the intercrop a yield advantage. However, yields of these landraces are low, on average 300-600 kg ha^{-1} (Musaana and Silim 1998, Silim et al. 1991), and, therefore, there is need to promote adoption of new high-yielding cultivars. One problem is that short-duration cultivars, e.g. Kat 60/8 and ICPL 87091 which were recently introduced, mature in 90-130 days, which more or less coincides with the maturity period of finger millet. Similarly, the introduced medium-duration varieties such as ICP 6927 tend to mature early in Uganda and could potentially compete with the main crop. The potential reduction in millet yield due to competition between the two crops highlights the importance of testing these materials in intercrop situations before making recommendations to farmers.

The main aim of the work reported in this paper, therefore, was to develop new production technologies involving the new cultivars and determine the most appropriate sowing patterns and plant populations of the component crops in order to minimize competition effects and ensure high yields of both crops.

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Experimental Work in Uganda

Research involving cereal/pigeonpea intercropping in Uganda has been conducted intermittently. Some work was carried out during the mid-seventies (1975-77) with funding from the International Development Research Centre (IDRC); but was discontinued because of lack of funding. More recently (1998/99), research on cereal/pigeonpea intercropping was initiated with funding from the European Union. This work focused largely on identifying optimal plant population and row arrangements for short-duration pigeonpea cultivars, thus minimizing competition at critical growth periods and maximizing complementary effects in the intercrop.

The earlier experiments (1975-77) examined combinations of finger millet/pigeonpea and sorghum/pigeonpea. The finger millet variety was Serere 1, which usually grows to a height of 70-80 cm and matures in about 110 days. The sorghum variety used was Dobbs, an improved local variety that was widely grown around the Lake Victoria crescent at that time. It matures in about 120 days. Two pigeonpea varieties were used - UC 11 for the millet/pigeonpea intercrop and Determinate Short for sorghum/pigeonpea. UC 11 is a dwarf Ugandan collection, shorter than Serere 1. Determinate Short is a high-yielding variety, slightly shorter than Dobbs, maturing in 124-130 days.

In the later experiments (1998/99), both finger millet/pigeonpea and sorghum/pigeonpea combinations were examined. The objective was to determine the appropriate row pattern, plant population, and cultivar suitability for these intercrop systems. As with the earlier experiments, a wide range of plant populations were used to ensure that the maximum productivity of intercrops could be compared with the maximum productivity of pure stands. The finger millet variety was Pese 1, short-statured, maturing in about 120 days. The sorghum varieties were Sekedo and Seredo.

Three pigeonpea varieties were used: ICP 6927 (medium duration), Kat 60/8 (early to medium duration), and ICPL 87091 (short duration). The experiments were carried out at Makerere University Agricultural Institute Kabanyolo (MUARIK) and Ngetta Experimental Station in Lira district. In the work involving finger millet, two sets of experiments were carried out. One examined the effects of plant population on pigeonpea intercropped with finger millet at different row patterns, while the other studied the effects of row patterns on three pigeonpea cultivars intercropped with finger millet.

Results, 1975-77

The results have generally shown that intercropping can provide yield benefits. Large yield benefits were achieved, with LERs of up to 1.30 and 1.29 in millet/pigeonpea and sorghum/pigeonpea mixtures respectively. Pigeonpea yields were low in all treatments, due to heavy disease infection and pest attack. When planted as sole crops, both finger millet and pigeonpea gave their highest yields at the highest plant populations - indicating that the plant populations used in the experiments were less than optimum.

The experiment also studied the effect (at each plant population) of replacing part of one crop by the other crop. For instance, when one-quarter of cereal was replaced by pigeonpea, the decrease in cereal yield could not be compensated by increased pigeonpea yield - total grain yield from the mixture was lower than from sole cereal. As more and more cereal was replaced with pigeonpea, there was a progressively significant decrease in cereal yield and the total yield of the mixture. However, at the highest plant population, and the lowest degree of substitution (25% of cereal replaced by pigeonpea), loss of cereal yield was largely compensated by increased pigeonpea yield.

Results, 1998/99

Results of experiments conducted in 1998/99 are summarized in Tables 1 to 4. Increasing plant population significantly ($p<0.05$) reduced the number of branches per plant, pods per plant, 100-seed mass, and dry matter per plant of pigeonpea in all row patterns. Plant height, however, significantly increased with increase in plant population, but the number of seeds per pod was not affected by either plant population or row pattern. The increase in dry matter per plant and pods per plant was due to increased branching at low plant populations and in intercrops. Increased branching in turn was due to increased space per plant, which reduced shading and therefore reduced intra-specific competition (Lawn and Troedson 1990, Ali 1990). This resulted in increased interception of radiation and consequently more pod formation. At very high plant populations, the reduction in the number of pods per plant could not be compensated for by the high number of plants per unit area, resulting in lower total yield. Intercropping significantly ($p<0.05$) increased the number of pods per plant at Ngetta compared to MUARIK.

Land equivalence ratios. LERs in all intercropping systems were higher than 1.0 (1.06-1.34 at MUARIK and 1.13-1.46 at Ngetta), indicating that intercropping pigeonpea with finger millet resulted in a yield advantage, and that Kat 60/8, a tall indeterminate variety, was suitable for such an intercrop (Table 1). Yields of the intercrop depended on both row pattern and intra-row spacing. The highest LERs were achieved from a 2:2 row pattern at pigeonpea intra-row spacings of 30 cm and 20 cm at MUARIK and Ngetta respectively.

When millet was sown in rows, LERs were above 1.0 for all row patterns. For intercrops where millet was broadcast, LERs were less than 1.0 (Table 2). Kat 60/8 and ICPL 87091 gave their highest LERs at 2:2 row patterns and ICP 6927 in 1:2 row pattern. These results indicated that for a given row arrangement, optimal planting pattern depended on the pigeonpea cultivar used.

Conclusions

The results of the experiments clearly indicated that the highest yield advantages were obtained at row patterns of 2:2 for Kat 60/8 and ICPL 87091; and at a 1:2 row pattern with ICP 6927. The advantages seem to be due to increased branching and podding of pigeonpea in intercrops, which more than compensated for the reduction in cereal population in the intercrop.

Table 1. Yield and LERs of Kat 60/8 intercropped with finger millet at various plant populations and row patterns, MUARIK and Ngetta, 1999 second season.

Row pattern	MUARIK					Ngetta				
	Yield (kg ha^{-1})		LER			Yield (kg ha^{-1})		LER		
	Pigeonpea	Millet	Pigeonpea	Millet	Total	Pigeonpea	Millet	Pigeonpea	Millet	Total
S, A	983	—	1.00	—	1.00	636	—	1.00	—	1.00
S, B	1070	—	1.00	—	1.00	726	—	1.00	—	1.00
S, C	1200	—	1.00	—	1.00	758	—	1.00	—	1.00
S, D	1043	—	1.00	—	1.00	680	—	1.00	—	1.00
1, A	835	354	0.85	0.27	1.12	489	200	0.79	0.30	1.09
1, B	933	515	0.87	0.30	1.17	584	245	0.80	0.30	1.10
1, C	1070	530	0.89	0.31	1.20	631	214	0.83	0.30	1.13
1, D	843	516	0.81	0.30	1.11	522	144	0.77	0.32	1.09
2, A	347	931	0.35	0.70	1.05	299	457	0.47	0.68	1.15
2, B	453	961	0.42	0.55	0.97	378	503	0.52	0.61	1.13
2, C	598	1046	0.50	0.60	1.10	436	461	0.58	0.64	1.22
2, D	433	976	0.42	0.56	0.98	324	273	0.48	0.61	1.09
M, A	—	1333	—	1.00	1.00	—	668	—	1.00	1.00
M, B	—	1737	—	1.00	1.00	—	823	—	1.00	1.00
M, C	—	1754	—	1.00	1.00	—	726	—	1.00	1.00
M, D	—	1740	—	1.00	1.00	—	446	—	1.00	1.00

S = sole pigeonpea, M= sole millet
1 = 2:2 row pattern, 2 = 1:4 row pattern
A= 40/20 cm, B = 30/15 cm, C= 20/10 cm, D = 10/5 cm pigeonpea/millet within-row distance

Table 2. Yield and LERs of Kat 60/8, ICP 6927, and ICPL 87091 intercropped with finger millet variety Pese at various row patterns, MUARIK and Ngetta, 1999 first season.

Treatment	MUARIK					Ngetta				
	Yield (kg ha^{-1})		LER			Yield (kg ha^{-1})		LER		
	Pigeonpea	Millet	Pigeonpea	Millet	Total	Pigeonpea	Millet	Pigeonpea	Millet	Total
ICPL 87091, 2:2	1177	1044	0.95	0.36	1.31	423	1183	0.66	0.64	1.30
ICPL 87091, 1:2	690	1382	0.56	0.48	1.04	188	1450	0.29	0.79	1.08
ICPL 87091, 1:4	428	1850	0.35	0.64	0.99	148	1717	0.23	0.96	1.17
ICPL 87091, 1:B	699	1137	0.56	0.40	0.96	138	1375	0.21	0.75	0.96
Sole ICPL 87091	1240	-	1.00	-	1.00	646	-	1.00	-	1.00
Kat 60/8, 2:2	1358	712	1.00	0.25	1.25	725	1217	0.67	0.66	1.33
Kat 60/8, 1:2	812	1308	0.60	0.46	1.06	300	1415	0.28	0.77	1.05
Kat 60/8, 1:4	692	1993	0.51	0.69	1.20	153	1803	0.14	0.98	1.12
Kat 60/8, 1:B	752	865	0.55	0.30	0.85	169	1233	0.16	0.67	0.83
Sole Kat 60/8	1357	-	1.00	-	1.00	1090	-	1.00	-	1.00
ICP 6927, 2:2	784	850	0.73	0.30	1.03	623	792	0.71	0.43	1.14
ICP 6927, 1:2	729	1217	0.68	0.42	1.10	525	1250	0.60	0.68	1.28
ICP 6927, 1:4	377	1907	0.35	0.66	1.01	250	1454	0.28	0.79	1.07
ICP 6927, 1:B	749	998	0.69	0.35	1.05	282	958	0.32	0.52	0.84
Sole ICP 6927	1079	-	1.00	-	1.00	883	-	1.00	-	1.00
Sole millet	-	2875	-	1.00	1.00	-	1838	-	1.00	1.00

Table 3. Yields and total LERs for pigeonpea intercropped with finger millet and sorghum, MUARIK, first season 1998.

Treatment	Yield (kg ha^{-1})				Total LER
	Pigeonpea	Finger millet	Sorghum	Combined	
PP1+FM(1:1)	864	640	-	1504	1.30
PP1+FM(1:2)	669	636	-	1305	1.16
PP1+FM (2:2)	907	839	-	1746	1.54
PP2+FM(1:1)	558	722	-	1310	1.37
PP2+FM(1:2)	391	928	-	1319	1.38
PP2+FM (2:2)	1010	701	-	1711	1.79
PP1+S (1:1)	433	-	1807	2240	0.95
PP1+S(1:2)	404	-	2594	2998	1.21
PP1+S (2:2)	777	-	2220	2997	1.35
PP2+S(1:1)	349	-	1547	1896	0.91
PP2+S (1:2)	334	-	1865	2199	1.00
PP2+S (2:2)	632	-	2247	2879	1.45
Sole PP1	1359	-	-	1359	1.00
Sole PP2	956	-	-	956	1.00
Sole FM	-	958	-	958	1.00
Sole S	-	-	2848	2848	1.00
LSD (0.05)	96.1	113.6	121.9	122.5	-
CV(%)	9.05	5.04	5.04	3.52	-

PP1 = Kat 60/8, PP2 = ICPL 87091, FM = Pese 1, S = Seredo (sorghum)

Table 4. Mean yields and LERs in pigeonpea/finger millet intercrops, Ngetta, 1998.

Intercrop and population (plants/m^2)	Yield (kg ha^{-1})			Total LER
	Pigeonpea	Finger millet	Combined	
PP1+FM (8.3:8.3)	1378	1472	2850	1.01
PP1+FM (5.6:11.1)	1098	1830	2928	0.99
PP1+FM (4.8:16.7)	798	2861	3650	1.14
PP1+FM (4.2:33.3)	709	3944	4655	1.40
PP2+FM (16.7:8.3	2345	1325	3670	1.19
PP2+FM (11.1:11.1)	1645	1428	3073	0.97
PP2+FM (8.8:16.7)	926	2200	3126	0.93
PP2+FM (5.6:33.3)	850	3156	4006	1.17
Sole PP1 (5.6)	2272	-	2272	1.00
Sole PP2 (8.3)	2844	-	2844	1.00
Sole FM (33.3)	-	3622	3622	1.00
LSD (0.05)	235.0	238.9	159.3	-
CV (%)	10.8	5.90	5.48	-

PP1 = Kat 60/8, PP2 = ICPL 87091, FM = Pese 1 (finger millet)

References

Ali, M. 1990. Pigeonpea cropping systems. Pages 279-301 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Shiela, V.K., eds). Wallingford, Oxon, UK: CAB International.

Lawn, R.J. and Troedson, RJ. 1990. Physiology of pigeonpea yield formation. Pages 179-208 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Shiela, V.K., eds). Wallingford, Oxon, UK: CAB International.

Musaana, M.S. and Silim, N.M. 1998. Path coefficient analysis of yield and its components in pigeonpea. African Crop Science Journal 6(2): 143-148.

Saxena, K.B. 1999. Pigeonpea production in Sri Lanka. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 98 pp.

Silim, S.N., Johansen, C., and Chauhan, Y.S. 1991. Agronomy of traditional and new cropping systems of pigeonpea and its potential for Africa. Pages 17-39 *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., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

The Potential of Pigeonpea-Cotton Intercropping in Uganda

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Introduction

Intercropping studies involving cotton with beans, maize, and cowpea have been conducted earlier (e.g. Elobo 1996). However, no experimental work has been documented for cotton-pigeonpea intercropping. Development of a cotton-pigeonpea system would allow the legume to benefit from cotton pest management, while cotton could benefit from the synergetic effects of the intercrop. A series of experiments were therefore conducted at Serere Agricultural and Animal Research Institute (SAARI) in Soroti district, Uganda during the two rainy seasons of 1999. The objective was to compare different spatial arrangements, varieties, pest control treatments, and plant densities.

Materials and Methods

The following factors were tested; treatments are listed in Table 1.

Table 1. Treatments used in cotton-pigeonpea intercopping studies, Serere, 1999.

	C-P*	C-C-P	C-C-C-P	C-C-P-P	C-P-P-P	P-sole	C-sole
First rainy season, planted 12 May							
ICPL 87091 (60 x 20 cm)	✔				✔	✔	
ICPL 87091 (75x20 cm)	✔	✔	✔	✔	✔	✔	✔
Kat 60/8 (75 x 30 cm)	✔	✔	✔	✔	✔	✔	✔
Adong (75 x 45 cm)		✔	✔			✔	✔
Second rainy season, planted 12 Aug							
ICPL 87091 (60 x 20 cm)	✔	✔	✔	✔	✔	✔	✔
ICPL 87091 (75 x 20 cm)	✔	✔	✔	✔	✔	✔	✔
Kat 60/8 (75 x 30 cm)	✔	✔	✔	✔	✔	✔	✔

*C-P: 1 row cotton, 1 row pigeonpea. C-C-P: 2 rows cotton, 1 row pigeonpea, etc

- *Spatial arrangement.* Various combinations such as 1 row cotton and 2 rows pigeonpea, etc were compared with sole cotton and sole pigeonpea.
- *Variety.* Three pigeonpea varieties were used: ICPL 87091 (short-duration determinate), Kat 60/8 (medium-duration indeterminate), and Adong (long-duration). The cotton variety used was BPA 97.

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- *Pest control.* Chemical pest control was applied on three blocks. Cypermethrin was applied on cotton only, starting 35 days after germination and repeated fortnightly to end of flowering. TWo control blocks had no pest control.
- *Plant density.* Pigeonpea variety Kat 60/8 was sown at 75 x 30 cm, Adong at 75 x 45cm. ICPL 87091 was sown at two densities, 75 x 20 cm and 60 x 20 cm. The cotton variety BPA 97 was also sown at two densities, 75 x 45 cm and 60 x 45 cm.

The experiments were conducted during the two rainy seasons of 1999, planted in May and Aug. Plot size was 6 x 5 m. The experiment was laid out in two unsprayed replications and three replications with pest control applied on cotton plants only. Treated and untreated treatments were separated by a 25 m strip planted with sorghum variety Secedo, sown at the same time. Adong was planted only during the first rainy season. ICPL 87091 and Kat 60/8 were ratooned to obtain a second harvest (not reported here).

In addition, 8 random plant samples were taken for each crop and for each treatment in five replicates, in order to determine the major biomass components. Finally, leaf fall was recorded in one treated and one untreated block.

Results and Discussion

Spatial arrangement

Land Equivalent Ratio (LER) was higher than one in all intercropping treatments (Table 2, Fig 1). This was due to the fact that per-area cotton yields were higher in intercrop treatments than in sole cotton. Further, as the share of the cotton component increased, total LER for the intercrop also increased. The highest LER during the first rainy season was obtained from treatment C-C-C-P, i.e. three rows of cotton with one row of pigeonpea. Cotton seed yield per unit area from this arrangement was about 30% higher than the monocrop treatment. Yields of pigeonpea, which occupied only 25% of the intercrop, were as high as 42% of the corresponding monocrop yield. In the second rainy season, yields of both crops were low as a result of drought and insect pests. However, as in the first season, LERs were high in all intercrops, underlining the benefits of this intercropping system.

Table 2. Yield performance of pigeonpea-cotton intercropped with different spatial arrangements.

Treatment	1st rainy season (planting date 12 May)			2nd rainy season (planting date 12 Aug)		
	Pigeonpea yield (kg ha^{-1})	Cotton yield (kg ha^{-1})	Total LER	Pigeonpea yield (kg ha^{-1})	Cotton yield (kg ha^{-1})	Total LER
C-P	318	1101	1.51	127	339	1.59
C-C-P	300	1148	1.51	75	378	1.23
C-C-C-P	194	1745	1.73	78	444	1.37
C-C-P-P	247	1050	1.32	105	351	1.43
C-P-P-P	490	519	1.45	151	117	1.41
C sole	0	1329	1.00		601	1.00
P sole	464	0	1.00	124	0	1.00

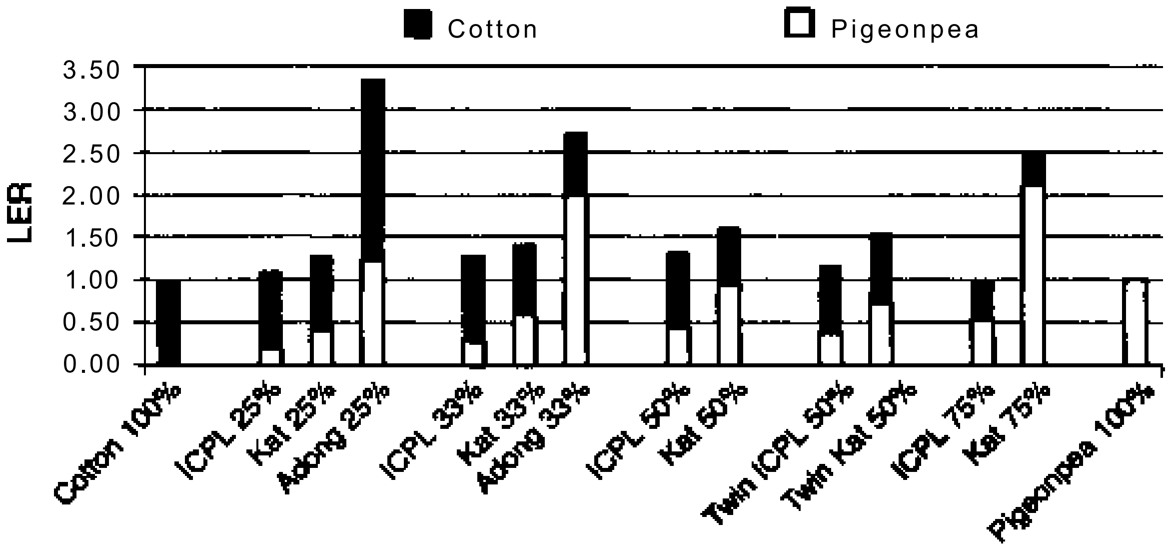

Figure 1. LERs from various cotton-pigeonpea intercrops, Serere, first rainy season 1999.

Effect of variety

Intercrop performance depended on the pigeonpea variety being used. In terms of yield of both crops and total LER, the local variety Adong was the best among the three pigeonpea cultivars used, followed by Kat 60/8 and ICPL 87091. Kat 60/8 gave a much higher LER than ICPL 87091, while competition effects were lower with Kat 60/8 than with ICPL 87091. These results can be explained by the different growth stages and hence the reduction of intercrop competition (Steiner 1982). Adong started flowering about 10 weeks later than cotton and harvest was even further delayed.

Pest control

In all treatments, pest control increased cotton yields (Table 3). Similar results were observed for pigeonpea, especially Kat 60/8 and ICPL 87091. Pest control was relatively more effective in Kat 60/8, because the flowering stage roughly coincided with that of cotton. The difference between treated and untreated plots was smallest in Adong, indicating some degree of pest tolerance.

Plant density

ICPL 87091 was planted at two densities, i.e. 75 x 20 cm and 60 x 20 cm. Increase in plant density increased pigeonpea yield in the intercropped treatments but reduced cotton yield (Table 3). High plant density also increased total LER: by 65% for the 75 x 20 cm spacing, and by 21 % for 60 x 20 cm, when pest control measures were taken. Performance was poor when no pest control was applied (e.g. LER < 1.0 at 60 x 20 cm spacing). This suggests that intercropping without pest control gave no yield advantages over a monocrop.

Biomass and nutrient transfer in pigeonpea-cotton intercrops

The importance of biomass and its components, including leaf fall, was measured in each of the intercropping systems. Fig. 2 shows the results of the experiment planted during the second rainy season. The collection of fallen leaves started 102 days after planting and was completed together with the last picking of cotton. Cotton produced the highest total biomass amount (leaf fall and plant weight). Hence, it follows that treatments with a high share of cotton (e.g. 75% or 3 rows of cotton with 1 pigeonpea row) produce the highest biomass. Plant density is another factor - cotton at lower plant density (row spacing 75 cm) produced more biomass than at higher density (60 cm). The medium-duration pigeonpea variety Kat 60/8 was taller and produced more biomass than the short-duration ICPL 87091. Similar results were reported by Nene et al. (1990).

Gross economic returns

Table 4 shows the estimated gross economic returns from different intercropping treatments. In 1999, the market price (Ugandan shillings) for cleaned seed cotton was 250 USh/kg and for shelled pigeonpea 500 USh/kg. The returns were highest when cotton was intercropped with pigeonpea variety Adong, particularly with 25% Adong (863 USh/ha). However, note that these are gross returns, and do not include input costs (labor, pesticides etc), which are considerable for cotton.

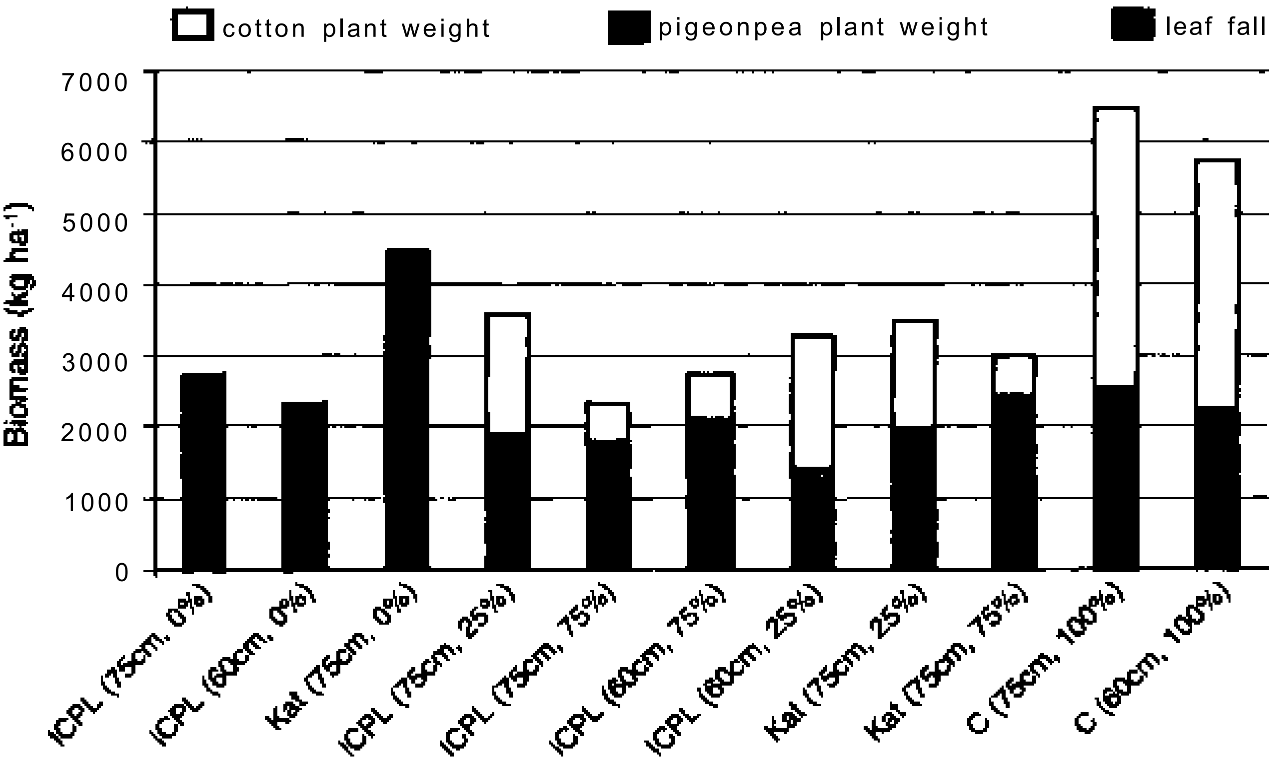

Figure 2. Biomass production in various cotton/pigeonpea intercrop combinations, Serere, second rainy season 1999.

Table 3. Cotton performance in various pigeonpea-cotton intercrop treatments, Serere, 1999.

Treatment	1st rainy season (planting date 12 May)				2nd rainy season (planting date 12 Aug)			
	Height (cm)	No. of branches	Ball weight (g)	No. of balls	Height (cm)	No. of branches	Ball weight (g)	No. of balls
ICPL 87091 (75 cm) with pest control	110	8	128.56	25.27	91	7	32.94	10.35
ICPL 87091 (75 cm) without pest control	104	10	51.80	13.14	104	7	11.48	4.78
ICPL 87091 (60 cm) with pest control	115	10	108.95	22.79	98	7	31.10	9.92
ICPL 87091 (60 cm) without pest control	116	10	45.39	10.50	104	8	9.69	4.33
Kat 60/8 (75 cm) with pest control	105	8	110.12	21.85	108	9	37.10	11.92
Kat 60/8 (75 cm) without pest control	138	13	58.76	14.23	114	8	11.29	4.73
Adong (75 cm) with pest control	106	8	85.06	17.04	-	-	-	-
Adong (75 cm) without pest control	138	12	65.42	14.06	-	-	-	-
Cotton (75 cm) with pest control	105	8	80.39	16.44	98	6	35.63	10.33
Cotton (75 cm) without pest control	114	11	48.50	11.38	89	6	31.55	9.50
Cotton (60 cm) with pest control	-	-	-	-	107	6	11.19	5.00
Cotton (60 cm) without pest control	-	-	-	-	94	4	12.96	5.00

Table 4. Gross economic returns from various pigeonpea-cotton intercrop treatments, Serere, first rainy season 1999.

Row arrangement	Variety, row spacing	Yield (kg ha^{-1})		LER			Gross returns (USh ha^{-1})		
		P	C	P	C	Total	P	C	Total
C-P	ICPL 87091, 75 cm	289	1175	0.45	0.88	1.34	144.5	293.7	438.1
C-C-P	"	177	1360	0.28	1.02	1.30	88.5	339.9	428.4
C-C-C-P	"	122	1232	0.19	0.93	1.12	60.8	308.1	368.9
C-C-P-P	"	248	1031	0.39	0.78	1.16	123.9	257.9	381.8
P-P-P-C	"	351	579	0.55	0.44	0.99	175.7	144.7	320.4
C-P	ICPL 87091, 60 cm	354	1223	0.57	0.92	1.49	176.9	305.7	482.6
C-P-P-P	"	416	454	0.67	0.34	1.01	207.9	113.4	321.3
C-C-P	Adong, 75 cm	527	983	1.97	0.74	2.71	263.7	245.8	509.6
C-C-C-P	"	327	2798	1.22	2.11	3.33	163.6	699.6	863.2
C-P	Kat 60/8, 75 cm	312	905	0.93	0.68	1.62	155.9	226.3	382.2
C-C-P	"	196	1102	0.59	0.83	1.42	98.1	275.5	373.6
C-C-C-P	"	133	1203	0.40	0.91	1.30	66.4	300.8	367.2
C-C-P-P	"	246	1069	0.74	0.80	1.54	122.9	267.2	390.1
P-P-P-C	"	701	524	2.10	0.39	2.50	350.7	131.1	481.8
Sole P	Adong	267	0	1.00		1.00	133.7	0	133.7
Sole P	ICPL 87091, 75 cm	638		1.00		1.00	318.9	0	318.9
Sole P	ICPL 87091, 60 cm	617		1.00		1.00	308.7	0	308.7
Sole P	Kat 60/8, 75 cm	333	0	1.00		1.00	166.7	0	166.7
Sole C	75 cm		1329		1.00	1.00	0	332.2	332.2

1 USD = 1500 USh

Single plant samples

Analysis of single plant samples of cotton and pigeonpea allows some preliminary conclusions to be drawn. In cotton, yields were higher during the first rainy season. Yield per single plant and number of balls were highest in the C-P-P-P treatment. For pigeonpea, the highest yield per single plant, and largest number of pods and seeds were obtained from the C-C-P and C-C-C-P treatments in both seasons. The higher the share of cotton, the higher the yield of pigeonpea. Plants in the C-C-C-P treatment were taller and more branched. Among the three varieties tested, the local variety Adong showed the highest seed weight and largest number of seeds and pods per plant. Adong also had fewer damaged seeds (24-31%) and failed pods, indicating a high degree of pest tolerance. The seeds are small and hard. The plants are much more branched and more than twice as tall as the the two improved varieties.

Conclusions

- All intercrop treatments gave yields higher than the corresponding monocrop, as measured by LER
- Crops planted during the first rainy season gave higher yields than crops planted during the second rains
- A high share of the cotton component increased total yield (LER) of the intercrop
- Yields and gross returns were highest in intercrops with the pigeonpea variety Adong
- Increasing plant density increased pigeonpea yield but reduced cotton yield
- Treatments with a high share of cotton produced the largest amount of biomass.

Acknowledgments

The research work reported in this paper was funded by the European Union as part of the project "Genetic improvement of pigeonpea and management of intercropping systems in the semi-arid areas of East Africa" (Contract no. ERBICIC 18CT 960130).

We are grateful to the staff of Serere Agricultural and Animal Research Institute who gave us all their support for our experimental work; especially Dr J Oryokot, Dr J P Esele, Mr H Okurut-Akol, Mr J Obuo, Mr M Ogwang, Mr R Omadi, Mr W Emokoll, Mrs R Eragu, Mr S Egemu, Mr A Omilya and all the others who although not mentioned here, were a great help. Eyalama noi noi!

References

Elobo, P. 1996. Annual report: Department of Cotton, Serere Agricultural and Animal Research Institute. Kampala, Uganda: National Agricultural Research Organisation.

Nene, Y.L., Hall, S.D., and Sheila, V.K. (eds) 1990. The pigeonpea. Wallingford, Oxon, UK: CAB International. 492 pp.

Steiner, K. 1982. Intercropping in tropical smallholder agriculture with special reference to West Africa. Eschborn, Germany: GTZ.

Potential of Short- and Medium-Duration Pigeonpea as Components of a Cereal Intercrop

C Smith[1], J P Baudoin[2] and G Mergeai[2]

Introduction

Pigeonpea is one of the most important grain legumes in Africa. The crop is commonly grown as a multi-purpose legume species intercropped or strip cropped with maize, sorghum, cowpea, greengram, and cucurbits (Le Roi 1997). Maize/pigeonpea is the dominant intercropping system, maize being the principal crop (Silim et al. 1991). The crop is grown under conditions characterized by poor soils and frequent drought. Farmers traditionally intercrop maize with pigeonpea landraces with little regard for spacing and population (Silim et al. 1995). Studies have earlier been carried out on spatial arrangement and plant population in cereal-pigeonpea intercrops, e.g. Silim et al. (1995). Information on the effect of plant population in intercropping mostly focuses on spacing between rows. However, during planting most farmers drill seeds in the furrow behind the plow, which does not allow much flexibility in inter-row spacings. Another way of studying the effect of densities in an intercrop is to alter the intra-row spacings while inter-row spacings remain constant. Rao and Willey (1983) showed that long-duration pigeonpea genotypes were ideal for intercropping with cereals. However, in Kenya, where severe terminal drought is frequent, long-duration pigeonpea varieties often fail to produce yield and researchers are looking at short- and medium-duration varieties as alternatives. As these duration groups are new in the region, there is need to determine appropriate production practices. The study reported here aimed at determining the effect of varying plant density in intercrops of maize with short- and medium-duration pigeonpea, so as to come up with a recommendation for farmer use.

Materials and Methods

Crop cultivation and management

The trial was conducted during the 1999 long rainy season under irrigation at Kenya Agricultural Research Institute (KARI) Thika Centre in Kenya, located at 1545 m altitude. The average minimum temperature recorded during the cropping season (Apr-Nov 1999) was 13.4°C. Information on the average maximum temperature was not available due to thermometer failure at the station. The experiment was a 2x2x4 set out in a split-plot design with four replicates. The densities used were 4.2, 5.5, 8.3, and 11.1 plants/m^2 representing 40, 30, 20, and 15 cm intra-row spacings. The main treatments were (i) sole pigeonpea,

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(ii) intercrop maize/pigeonpea. Sub-plot treatments were four plant spacings within rows: (i) pigeonpea 11.1 plants/m^2, maize 4.2 plants/m^2, (ii) pigeonpea 8.3 plants/m^2, maize 5.5 plants/m^2, (iii) pigeonpea 5.5 plants/m^2, maize 8.3 plants/m^2, (iv) pigeonpea 4.2 plants/m^2, maize 11.1 plants/m^2 and two pigeonpea varieties, i.e. Kat 60/8 (medium indeterminate) and ICPL 87091 (short-duration determinate). The variety of maize used was Pioneer hybrid which is a locally improved variety adapted to highlands. In order to assess the advantages or disadvantages of growing intercropped maize versus sole maize at the four densities, four sole crops of maize were added.

The experiment was sown on 21-22 April. Diammonium phosphate (DAP 18-46-0) was applied only to maize rows at sowing time at the rate of 150 kg ha^{-1}. The inter-row spacing was 60 cm and the row proportion was 2:2 in intercrop, leaving crops at 50% of their equivalent sole-crop plant population. Paired-row spatial arrangement was selected because it allows more radiation to reach the crop grown between the cereal rows (Ali 1990). Each plot measured 5.5 x 7.8 m. Two seeds of maize and five seeds of pigeonpea were sown at the required distance. Maize was thinned to one plant per hill and pigeonpea to two plants per hill. Maize was harvested in Oct 1999 and both pigeonpea varieties in Nov 1999.

Observations and data analysis

Pigeonpea: Observations were made on phenology (days to flowering, pod set and maturity), on morphology (plant height, stem thickness, and number of primary branches at maturity), yield parameters (pods per plant and seeds per pod), and the main insect pests causing pod damage. *Maize:* Observations were made on stalk thickness and number of cobs per plant.

At maturity an area of 2.4 x 4.5 m (10.8 m^2) was harvested per plot to estimate total grain yield for both maize and the two pigeonpea varieties. The productivity of the system was assessed by calculating the land equivalent ratios (LERs) based on the method of Mead and Willey(1980):

LER = LP + LM = (Ypm/Ypp) + (Ymp/Ymm)

where Y is the yield per unit area, Ymm and Ypp the sole-crop yields of maize and pigeonpea, Ypm and Ymp the respective yields of pigeonpea and maize in intercrops.

Data were analyzed using Genstat 5. The assumptions that validate the analysis of variance were checked by plotting the residuals against the fitted values.

Results

Plant growth

The effect of plant spacing within rows on pigeonpea growth is shown in Table 1. There was no difference in phenology, height, and number of branches at maturity under sole and intercropping. Though the difference was not significant, the stems were thicker in the sole crop (5.8 mm) than in the intercrop (5.0 mm). There were significant differences among the four spacings, with increasing plant density tending to reduce the stem diameter.

Table 1. Plant growth of two pigeonpea cultivars at four plant densities, Thika KARI Station, Kenya, long rains 1999.

Density (plants/m^2)	Cultivar	Days to 50% flowering	Days to 75% maturity	Plant height (cm)	No. of branches
11.1	ICPL 87091	106	177.62	46.55	13.03
	Kat 60/8	119.37	186.62	81.80	16.25
8.3	ICPL 87091	105.62	179.75	48.57	12.92
	Kat 60/8	117.25	193.12	86.65	18.92
5.5	ICPL 87091	106	179.12	48.97	13.17
	Kat 60/8	117.87	190.12	87.95	17.10
4.2	ICPL 87091	105.62	179.12	48.37	13.60
	Kat 60/8	123.75	194.37	83.07	15.45
Intra-row spacing (IS)		ns	ns	ns	ns
Pigeonpea cultivar (PC)		***	***	***	***
IS x PC		ns	ns	ns	ns
SED (%)	IS	1.945	2.454	2.752	0.834
	PC	1.375	1.735	1.946	0.590

*significant at 5% probability level, ***significant at 0.1% probability level

Pest damage

Pod and seed damage by all pests differed significantly among cultivars, with ICPL 87091 being the most affected. Neither cropping system nor plant population had any effect on pest incidence.

Crop yield

Grain yields for maize and pigeonpea are shown in Table 2. After plotting the residuals against the fitted values, a systemic pattern was observed for pigeonpea yield values, showing violation of the assumptions validating the ANOVA. A log transformation of the data best gave rise to a random scatter graph of residuals and was then used for the analysis of variance.

Maize grain yields (per hectare) in intercrops were 72% of sole-crop yields, showing a decline due to intercropping. No differences were found in maize grain yields between the four densities. Pigeonpea grain yields in intercrops were reduced to 34% of the sole-crop values, showing a negative effect of intercropping. There was significant interaction between the two cropping systems and the plant density. Regression lines ($P<0.001$) were fitted to the pigeonpea yield means for each cropping system separately. Though decreasing pigeonpea plant density consistently reduced yields in both cropping systems, the response was higher in intercropping. The yields of Kat 60/8 and ICPL 87091 differed significantly ($P<0.001$) in both sole crop and intercrop, with ICPL 87091 producing the lowest yield.

The grain yield components of pigeonpea and maize are shown in Tables 3 and 4. In maize the intercrops had more cobs per plant and larger grain size. Increasing maize plant density reduced progressively the average grain size. In pigeonpea, intercrops had fewer pods per plant than the respective sole crops. An interaction was also found between the cropping system and the intra-row spacing. The relationship between number of pods and increasing pigeonpea plant density was positive in the intercrop and negative in the sole crop. The number of seeds per pod was not affected by any of the factors. Average seed size in both cultivars differed significantly between the two cropping systems.

Absolute pigeonpea yields were positively correlated to the number of pods ($P<0.01$) and the number of seeds (non significant) and negatively correlated to seed size ($P<0.01$). Maize grain yield was negatively correlated to both number of cobs ($P<0.05$) and seed size ($P<0.01$).

Land equivalent ratios

Most LERs were lower than 1 because of the poor pigeonpea yields in intercrops (Table 5). The highest yielding combination overall was Kat 60/8 at 5.5 plants/m^2 intercropped with maize at 8.3 plants/m^2. However, the yield advantage was very small (1%). The relative biological efficiency of the intercrops for each pigeonpea cultivar is shown in Table 5. In ICPL 87091, maximum LER was achieved when pigeonpea at 5.5 plants/m^2 was intercropped with maize at 8.3 plants/m^2, with a yield advantage of 3%. The yield proportion of maize [$LER_m/(LER_m+LER_p)$] within the most efficient combination was 0.75 for each

Table 2. Grain yield (kg ha^{-1}) of two pigeonpea cultivars at four plant densities in sole crop and intercrop, Thika KARI Station, long rains 1999.

Plants/m²	Cultivar	Sole maize	Intercrop maize	Sole pigeonpea		Intercrop pigeonpea	
				Original value	Transformed value	Original value	Transformed value
11.1	ICPL 87091	-	5068	558	6.26	215	5.35
	Kat 60/8	-	4270	1620	7.36	734	6.54
	Maize	5549	-				
8.3	ICPL 87091	-	4608	493	6.15	154	5.03
	Kat 60/8	-	4487	1592	7.27	510	6.21
	Maize	5910	-				
5.5	ICPL 87091	-	4354	368	5.89	143	4.92
	Kat 60/8	-	3602	1262	7.03	411	5.99
	Maize	5565	-				
4.2	ICPL 87091	-	2856	450	6.04	82	4.32
	Kat 60/8	-	2988	872	6.72	188	5.18
	Maize	5125	-				
Cropping system (CS)			*			***	
Intra-row spacing (IS)			ns			***	
Pigeonpea cultivar (PC)			-			***	
CS x IS			ns			*	
CS x PC, IS x PC, CSxPCxIS			ns			ns	
SED (%)	CS		266.8			0.072b	
	IS		551.6			0.131b	
	PC		-			0.092b	
	CS x IS		764.6			0.175b	

*significant at 5% probability level, ***significant at 0.1% probability level

Table 3. Grain yield components of maize at four plant densities in sole crop and intercrop, Thika KARI Station, long rains 1999.

Cropping system		Density (plants/m^2)	Cobs/plant	100-seed mass (g)
Sole crop		11.1	1.00	36.20
		8.3	1.00	35.35
		5.5	1.00	35.80
		4.2	1.00	38.45
Intercrop		11.1	1.00	37.48
		8.3	1.02	37.88
		5.5	1.05	40.55
		4.2	1.10	40.01
Cropping system (CS)			*	**
Intra-row spacing (IS)			ns	*
CS xIS			ns	ns
SED (%)	CS		0.012	0.332
	IS		0.027	1.033

*significant at 5% probability level, ***significant at 0.1 % probability level

pigeonpea cultivar. Individual LERs of maize indicate a general yield advantage of intercrops over sole maize, increasing consistently with maize plant density. In pigeonpea, all individual LERs were below 0.5, showing no benefit of intercropping. Although a general decline of individual LER with decreasing plant density can be observed, total LER did not show a similar trend.

Discussion

Intercropping effect on grain yield differed between crops. Maize was positively affected; the yield advantage in the intercrops was due to bigger grain and more cobs per plant than in the respective sole crops. Both pigeonpea varieties showed no yield advantage in intercrops due to a reduction in the number of pods per plant. Willey et al. (1981) reported that in the traditional sorghum/pigeonpea cropping system, high sorghum yields were maintained but pigeonpea yield was adversely affected; however if both species were grown using improved genotypes sown at full sole-crop population, the pigeonpea yield could be considerably increased without greatly lowering the contribution of the cereal (Reddy and Willey 1985). In this study, maize seems to have competed vigorously with pigeonpea.

The low temperatures experienced during the cropping season may explain the generally poor performance of the normally high-yielding ICPL 87091 and Kat 60/8. The negative influence of cool weather on performances of short- and medium-duration pigeonpea varieties has been reported by Silim et al. (1995) in a study of the Kenyan transect, which is located near the Equator (1° 15' to 4°25' S) with altitudes varying from to 0 to over 1800 m. The lack of vigor in pigeonpea would have then favoured maize competitiveness in the intercrops. Short-duration varieties are also known to respond poorly to intercropping with cereals compared to medium- and long-duration ones (Omanga et al. 1992). However, in this

Table 4. Grain yield components of two pigeonpea cultivars at four plant densities in sole crop and intercrop, Thika KARI Station, long rains 1999.

Density (plants/m²)	Cultivar	Pods/plant		Seeds/pod		100-seed mass (g)	
		Sole crop	Intercrop	Sole crop	Intercrop	Sole crop	Intercrop
11.1	ICPL 87091	35.6	21.7	5.3	5.3	13.78	13.5
	Kat 60/8	44.3	44.9	5	5.6	11.62	12.35
8.3	ICPL 87091	39.5	20.6	5	5.4	13.12	13.4
	Kat 60/8	56.6	45.6	5.3	5.3	11.7	12.8
5.5	ICPL 87091	31.6	23.6	5.05	5	13.25	13.37
	Kat 60/8	70.4	42.8	5.6	5.25	12.35	12.67
4.2	ICPL 87091	45.4	18.6	5.25	5.05	13.45	13.47
	Kat 60/8	83.4	33.3	4.95	5	12.1	12.85
Cropping system (CS)		*		ns		ns	
Intra-row spacing (IS)		ns		ns		ns	
Pigeonpea cultivar (PC)		***		ns		***	
CS x IS		**		ns		ns	
CS x PC		ns		ns		**	
ISxPC, CSxPCxIS		ns		ns		ns	
SED (%)	CS	5.46		0.054		0.135	
	IS	4.20		0.169		0.163	
	PC	2.97		0.120		0.115	
	CS x IS	7.50		0.215		0.241	
	CS x PC	6.21		0.132		0.178	

*significant at 5% probability level, **significant at 1% probability level, ***significant at 0.1% probability level

Table 5. LER of two pigeonpea cultivars in intercrop with maize, Thika KARI Station, long rains 1999.

Pigeonpea cultivar	Density (plants/m²)		LER using specific best sole genotype				LER using best sole genotype		
	Pigeonpea	Maize	Pigeonpea[1]	Maize[3]	Total	Yield proportion of maize[4]	Pigeonpea[2]	Maize[3]	Total
ICPL 87091	11.1	4.2	0.39	0.48	0.87	0.55	0.13	0.48	0.61
	8.3	5.5	0.28	0.74	1.01	0.73	0.09	0.74	0.83
	5.5	8.3	0.26	0.78	1.03	0.75	0.09	0.78	0.87
	4.2	11.1	0.15	0.85	1.00	0.85	0.05	0.86	0.91
Kat 60/8	11.1	4.2	0.45	0.51	0.96	0.53	0.45	0.51	0.96
	8.3	5.5	0.32	0.61	0.92	0.66	0.32	0.61	0.92
	5.5	8.3	0.25	0.76	1.01	0.75	0.25	0.76	1.01
	4.2	11.1	0.12	0.72	0.84	0.86	0.12	0.72	0.84

1. Sole ICPL 87091 at 11.1 plants/m² (558 kg ha^{-1}). Sole Kat 60/8 at 11.1 plants/m² (1620 kg ha^{-1})
2. Sole Kat 60/8 at 11.1 plants/m² (1620 kg ha^{-1})
3. Sole maize at 8.3 plants/m² (5910 kg ha^{-1})
4. Yield proportion of maize = LERmaize/(LERmaize+LERpigeonpea)

trial no interaction was observed between the cropping system and the cultivars used; despite differences in phenology (20 days), both pigeonpea cultivars started flowering when maize had not completed its growth cycle so that at a period of high nutrient demand, the two varieties were subjected to similar competition from maize. Yield loss was greater in ICPL 87091 than in Kat 60/8 probably because of higher pest infestation.

The positive relationship between pigeonpea yields and increasing plant density suggests a better use of resources at narrower spacings. Natarajan and Willey (1980) observed that in sorghum/pigeonpea intercropping, an increase in pigeonpea population improved light interception and productivity. However, high plant density might not be as suitable in environments subject to higher water deficit, due to increased competition for soil moisture. Rees (1986) found that sorghum/cowpea intercrops were disadvantageous at medium densities in dry conditions but beneficial in moist conditions.

The results also show that decreasing pigeonpea plant density reduced pigeonpea yields more rapidly in intercrops than in sole crops, probably as a result of increasing competition from maize. In maize the negative relationship between yield and seed size indicates that though maize plants set bigger grain at wide spacings, this does not compensate for the low plant population.

LER tended to be lowest when there was an imbalance in the densities of the two crops, suggesting that intercropping should be beneficial when the two species are sown at equivalent densities. However, the total LERs were generally low, either less than or slightly greater than 1, suggesting that the different systems studied show little potential.

Acknowledgments

The research work reported in this paper was funded by the European Union under the project "Genetic improvement of pigeonpea and management of intercropping systems in the semi-arid areas of East Africa" (Contract no. ERBICIC 18CT 960130).

References

Ali, M. 1990. Cropping systems. Pages 279-301 *in* The pigeonpea (Nene, Y.L., Hall, S.D., and Sheila, V.K., eds). Wallingford, Oxon, UK: CAB International.

Le Roi, A. 1997. Evaluation of the situation of pigeonpea production in the semi-arid areas of Kenya. MSc thesis, University of Gembloux, Belgium.

Mead, R. and Willey, R.W. 1980. The concept of a 'Land Equivalent Ratio' and advantages in yield from intercropping. Experimental Agriculture 16:217-228.

Natarajan, M. and Willey, R.W. 1980. Sorghum-pigeonpea intercropping and the effects of plant population density. 2. Resource use. Journal of Agricultural Science, Cambridge 95: 59-65.

Omanga, P.G.A., Siambi, M., Shakoor, A., and Wafula, B.M. 1992. Improved pigeonpea cultivars and production technology. Pages 29-35 *in* Consultative Group Meeting on

Production and Agro-Processing of Sorghum and Pigeonpea in Kenya, Nairobi, Kenya. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Rao, M.R. 1983. Effects of genotype in cereal/pigeonpea intercropping on the Alfisols of the semi-arid tropics of India. Experimental Agriculture 19:67-78.

Reddy, M.S. and Willey, R.W. 1985. Evaluation of alternate cropping systems for Alfisols of the Indian semi-arid tropics. Experimental Agriculture 21:271-280.

Rees, D.J. 1986. Crop growth, development and yield in semi-arid conditions in Botswana. II. The effects of intercropping *Sorghum bicolor* with *Vigna unguiculata.* Experimental Agriculture 22:169-177.

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 Legume (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Silim, S.N., Omanga, P.A., Johansen, C., Laxman Singh, and Kimani,, P.M. 1995. Use of Kenya transect for selecting and targeting adapted cultivars to appropriate production systems. Pages 44-54 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Silim, S.N., Laxman, Singh, and Omanga, P.A. 1995. Development of agronomy of short-duration pigeonpea. Pages 38-43 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Willey, R.W., Rao, M.R., and Natarajan, M. 1981. Traditional cropping systems with pigeonpea and their improvement. Pages 11-25 *in* Vol. 1, Proceedings of the International Workshop on Pigeonpea, 15-19 Dec 1980, Hyderabad, India. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Discussions - Crop Management

Short-duration pigeonpea is not suitable for intercropping. It is best sole-cropped, but requires attention to insect pest management. Medium- and long-duration varieties are suitable for intercrops (and have traditionally been intercropped with cereals) because the initial growth is slow, minimizing competition with maize.

Spacing and plant population

A number of studies have been conducted on optimal cropping systems and intercrop combinations. The advantages of cereal-pigeonpea intercropping are unquestionable, but experiments on spacing, row patterns, plant densities etc have yet to yield precise recommendations. These recommendations are likely to be highly location-specific, particularly since pigeonpea is sensitive to changes in temperature and photoperiod.

In general, smallholders tend to use lower-than-desirable plant populations. Spacing as low as 30 cm between rows has been successfully tried under irrigation, but farmers continue to use spacings of 70-80 cm or more, which is wasteful of resources. Optimal spacing also depends on availability of soil moisture. Under dry conditions pigeonpea plants do not grow large and therefore higher densities are more efficient. In wet environments, when plant growth is more luxuriant, low density is more suitable.

Technology Exchange

Pigeonpea Technology Exchange - Strategies, Experiences, and Lessons Learnt in Eastern and Southern Africa

R B Jones, H A Freeman, and S N Silim[1]

Introduction

The Pigeonpea Improvement Project for Eastern and Southern Africa was initiated in 1992 with the goal of increasing pigeonpea productivity in the region. By 1996, the project had made significant progress in developing improved varieties, understanding markets, and identifying constraints to consumption. How could the technologies and knowledge developed through the combined efforts of ICRISAT and its collaborators be disseminated to achieve widespread impact?

The traditional research paradigm has assumed that technologies developed by research will be passed to extension, and then disseminated to farmers. In the highly regulated environment under which African agriculture operated until the late 1980s, there are examples of widespread adoption of productivity-enhancing technologies such as hybrid maize and fertilizer in Malawi (Heisey and Smale 1995). Until then, African governments used the colonial model of government marketing boards to control both input and market prices paid for agricultural produce (Eicher 1999). In many cases, the system was used to tax export crops and pump the economic surplus out of agriculture (Jones 1972). However, by the late 1980s, there was an increasing trend toward liberalized domestic markets and an opening up of economies to the forces of international trade. In particular, the move towards outward-oriented policies recognized the importance of exports as an important source of economic growth. This fundamental change in agricultural policy necessitated the adoption of a different approach to technology exchange by the Pigeonpea Improvement Project.

The process of technology exchange is defined by ICRISAT as:

- Dissemination of knowledge, information and research outputs to partners and other stakeholders; and
- input and feedback of knowledge, ideas and experiences to ICRISAT from farmers and other stakeholders;
- to enhance the relevance, effectiveness, and utilization of research outputs in support of the development process in the semi-arid tropics (Heinrich et al. 1997).

To effect change in agricultural development, a coordinated and focused approach is necessary among the various actors involved. The comparative advantage of an international agricultural research institute such as ICRISAT is in working in collaboration with national agricultural research and extension systems in technology development and

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dissemination. But in an emerging market economy, the real test of success of technological innovation is not in the test plot or the laboratory, but in the marketplace, which includes the range of actors within the broad web of input supply, production, harvest/storage, processing, and marketing (Jones et al. 1999).

Increased productivity is an important goal in itself, but studies of smallholder farmers have shown that, other things being equal, productivity increases of approximately 100% are often required before they are likely to adopt a new technology (CIMMYT 1988). Thus, the ability of research alone to create adequate incentives for technology adoption is limited. And yet technology adoption is essential for future growth and development. The challenge is to create other incentives for the adoption of these new technologies - but neither ICRISAT nor its NARES partners have comparative advantage in markets or business development.

This paper describes the strategies, experiences, and lessons learnt in the design and implementation of the technology exchange program in support of the Pigeonpea Improvement Project.

Strategic Partnerships for Sustainable Development

Before embarking on the technology exchange program, it was necessary to develop a number of strategic partnerships. What are partners and what is partnership? The Shorter Oxford English Dictionary defines partner as "(i) one who has a share or part with another or others; a partaker, sharer, (ii) one who is associated with another or others in some business, the expenses, profits, and losses of which he proportionately shares". Partnership is defined as "an association of two or more persons for the carrying on of a business, of which they share the expenses, profit and loss." It is not worth the effort of developing a partnership if we cannot see an outcome. Partnerships that simply feel good but are not productive are no longer sufficient (Foege 1999).

Specific objectives of the Pigeonpea Improvement Project were to:

- Strengthen national capacities for research and technology exchange
- Introduce and develop improved genetic material that national programs could further test and release for cultivation
- Develop and disseminate crop management technologies to improve system productivity and sustainability
- Strengthen seed production and delivery systems
- Develop and disseminate technologies to improve processing, utilization, and storage
- Identify ways to improve the marketing of pigeonpea (ICRISAT 1998).

Decisions had to be made on where the greatest impact could be achieved in the shortest possible time, and then to develop the strategic partnerships necessary to achieve the desired outcome.

From our understanding of the pigeonpea sub-sector in Eastern and Southern Africa, it was clear that strong market demand had stimulated increased production, largely through an expansion of the area planted to pigeonpea. Although statistics were woefully lacking, two examples of rapid area expansion stood out - Arusha region in northern Tanzania and Zambezia Province in northern Mozambique. Research also showed that both areas were not only linked to the Indian market, but also to significant markets in neighboring countries. In the case of Tanzania, this was to Kenya, and for Mozambique to southern Malawi (Ackello-Ogutu and Echessah 1998, Minde and Nakhumwa 1998). Related research highlighted the important role that pigeonpea plays in sustainable livelihoods for smallholder farmers cultivating less than 0.5 ha in southern Malawi, disproving the fallacy that poor smallholders only grow pigeonpea for food, and not for sale (Mwale et al. 1999). For this reason, emphasis was placed on developing strategic partnerships with the private sector. Would such partnerships be sustainable?

"Sustainable'' has become one of the most abused words in the lexicon of agricultural development. However, it is an important concept that needs to be carefully considered in the design and implementation of any development program. The litmus test for sustainability in development is the continuation of initiatives beyond the life of the project. If farmers, traders, and processors could all profit from pigeonpea, the chances of ensuring the sustainability of the technology exchange process would be enhanced.

Technology Exchange Models

Improved germplasm

In Eastern and Southern Africa, three pigeonpea maturity groups are recognized; long-duration, medium-duration, and short-duration. Short-duration varieties are semi-determinate and mature in 120 days while the medium- and long-duration types are indeterminate and take 160-300 days to mature. Short-duration determinate varieties are daylength-insensitive while the medium- and long-duration types are sensitive to both daylength and temperature. Short-duration varieties have the highest yield potential while medium- and long-duration varieties are similar.

One of the original justifications for the pigeonpea project was the expectation that adoption of improved short-duration varieties would lead to significant productivity increases. The project assembled and distributed large numbers of improved pigeonpea lines to collaborators in national agricultural research and extension systems, who in turn reported promising results with several genotypes. However, it soon became apparent that this traditional approach to germplasm development had limitations. First, although short-duration varieties showed great potential in on-station trials where insect pests were controlled, they often failed to yield under farmer management when no pest control measures were applied. Second, short-duration varieties did not perform well when intercropped with cereals, the traditional way of cultivating the local long-duration landraces throughout the region. The project recognized that unless technologies were carefully targeted, farmers were unlikely to adopt short-duration varieties.

There are several successful examples of insect pest management on cotton grown by smallholders in Eastern and Southern Africa. Why not investigate the possibility of targeting cotton fanners to grow short-duration pigeonpea? TechnoServe, a US-based NGO specializing in enterprise development, conducted a sub-sector analysis on cotton and pigeonpea in northern Mozambique. The purpose was to develop a detailed understanding of the players involved in the production and marketing chain, and to identify areas for leveraged interventions to increase farmers' returns. Their analysis found that pigeonpea prices in India, the dominant producer and consumer of the crop, tended to peak in the period May-Sep, just before the Indian crop is harvested. This explained why farmers in northern Mozambique, who were only growing long-duration varieties that were not harvested until late Sep, were not getting very high prices. These findings were confirmed when a group of Indian millers was invited to the country, and expressed an interest in purchasing up to 100,000 t of the crop provided delivery could be made in the period May-Sep when they are short of product to mill into *dhal.* By introducing short-duration varieties, it would be possible to harvest the crop several months earlier, and export to India when prices are higher.

Several cotton companies expressed an interest in working with TechnoServe based on the business plan presented to them, which showed that export of short-duration pigeonpea was a viable business. There were additional benefits including the rotation of cotton with a nitrogen-fixing legume crop that would boost cotton yields, and crop diversification at a time when global cotton prices were depressed.

It is too early to judge the success of short-duration pigeonpea in Mozambique. However, the issue of seed supply, and the ability of the cotton companies to provide the necessary institutional support to cotton farmers, have emerged as important constraints. Just as ICRISAT and its NARES partners do not have a comparative advantage in the marketplace, institutions such as TechnoServe do not have the technical background in seed production and farmer organization.

Kenya, with its well-developed horticultural industry, has exported small quantities of fresh pigeonpea to the UK for several years. The smallholder growers have contracts directly with the exporters, who can readily supply essential inputs. This trade was very seasonal in nature because of the phenology of the traditional long-duration varieties grown by farmers. With the introduction of short- and medium-duration determinate varieties that are less sensitive to temperature and photoperiod, it is now possible to supply fresh pigeonpea year round.

In 1999, ICRISAT approached a horticultural exporter to see if they would be interested in exporting green pigeonpea. It was agreed that a student from the University of Nairobi would test 15 improved short-duration varieties to determine their storability and sugar content within the existing delivery chain used by the horticultural exporter, while at the same time samples would be sent to the UK for market evaluation. The improved short-duration variety ICPL 87091 was identified both by the student and the UK buyers as having the longest shelf life and meeting the UK market requirements because of its attractive green seeds. Regular exports of fresh green pigeonpea are now taking place.

The export of green pigeonpea provides a good example of the different approach to technology exchange that is required to achieve impact. The horticultural exporter had never heard of ICRISAT or pigeonpea before they were approached, but based on information supplied they were willing to work with ICRISAT and the University of Nairobi to investigate the potential of the fresh pigeonpea market Farmers have benefited by being contracted to grow the crop for export, with a gross return of US$ 2000 ha^{-1} compared to $500 ha^{-1} for dry grain.

Processing and utilization

In 1997, a participatory research needs assessment was carried out with farmers in Kenya (Le Roi 1997). The assessment found that although pigeonpea is widely grown in the area, consumers prefer *Phaseolus* beans, at least in the dry form. Pigeonpea is considered hard to store, takes time to cook, and has a bitter taste imparted by the seed coat. In India, pigeonpea is mainly consumed as *dhal,* which is prepared either at home or industrially by dehulling and splitting the cotyledons. A visit to India by project collaborators in 1996 identified two technologies with potential for application in Eastern and Southern Africa - the stone *chakki* and mini-dehuller.

Before either of these technologies could be promoted, it was necessary to see how they could be made locally as the cost of importation from India was prohibitive. An artisan was identified in Nairobi who was already manufacturing *chakkis* out of cement in response to demand from members of the Asian community. The project arranged a meeting with a local artisan in Machakos, and together they developed a prototype *chakki* molded from cement, using materials that could be sourced locally. At the same time, women from pigeonpea-growing areas were being trained in improved processing and utilization technologies by staff from the Kenya Agricultural Research Institute who had been exposed to improved processing and utilization technologies both in India and at home. To train people in processing and utilization, it is necessary to have the capacity to dehull the pigeonpea. The development of the cement *chakki* was an important component in the overall strategy to increase consumption, and hence demand. Increased demand will, in turn, stimulate the adoption of productivity-enhancing technologies.

The most successful efforts to promote the manufacture of cement *chakkis* has been in the informal sector. *Chakki* manufacture is being promoted as a profitable business. The popularization of pigeonpea consumption in the processed form is a necessary complement to the technology exchange process, because without demand for *dhal,* there will be no demand for *chakkis.*

Discussion

Before a successful technology exchange program can be developed, it is first necessary to have a detailed understanding of the wider environment in which the technologies are to be promoted. For pigeonpea, the understanding of the marketing chain was particularly important at a time when most governments in Eastern and Southern Africa were adopting outward-oriented policies that recognized the importance of export markets. Second, researchers have to be far more aware of the wider environment in which they operate, from understanding market requirements to knowing how different technologies perform in real life situations. With this understanding, a technology exchange strategy can then be designed with clearly articulated outcomes. Third, strategic partnerships need to be developed to address the identified outcomes, by selecting partners based on their comparative advantages in the areas of expertise required to achieve the identified outcomes. The establishment of effective partnerships requires that everybody is clear about their respective roles and responsibilities, and that there is a fair and equitable allocation of resources to carry out the work required. For pigeonpea, emphasis was placed on developing partnerships with the private sector, as they are primarily responsible for marketing and processing of the crop. Finally, technology exchange is an iterative process which requires that all partners remain engaged in the technology exchange process. There was a perception among some researchers that the development of links to the private sector excluded research from the technology exchange process. This was incorrect, as already problems have been identified in the promotion of "first generation" technologies that require the renewed efforts of researchers if we are to be successful in addressing the needs of both farmers and end-users. A good example is the urgent need to develop short-duration pigeonpea varieties with better resistance to insect pests and fusarium wilt than the released "first generation" technologies. Based on our understanding of the pigeonpea sub-sector, we are now in a much better position to carry out research for development, which is well focused and hence more likely to have a positive impact on the lives of the poor.

Acknowledgments

The support of the African Development Bank in funding the Project for the Improvement of Pigeonpea in Eastern and Southern Africa, through which much of the work described was funded, is gratefully acknowledged.

References

Ackello-Ogutu, C. and Echessah, P.N. 1998. Unrecorded cross-border trade between Tanzania and her neighbors. Technical Paper No. 89. Washington DC, USA: Bureau for Africa, Office of Sustainable Development, Productive Sector Growth and Environment Division, USAID. 80 pp.

Eicher, C.K. 1999. Institutions and the African farmer: Third Distinguished Economist Lecture. Mexico, DF: CIMMYT. 37 pp.

Foege, W. 1999. Good partnerships and productive partnerships. Pages 10-13 *in* Partnerships for rural development in sub-Saharan Africa (Breth, S.A., ed). Geneva, Switzerland: Centre for Applied Studies in International Negotiations.

Heinrich, G.M., Russell, J.T., and Jones, R.B. 1997. Technology exchange policies and procedures: current approaches and proposals for the future from ICRISAT-Southern and Eastern Africa. PO Box 776, Bulawayo, Zimbabwe: ICRISAT (limited distribution).

Heisey, P.W. and Smale, M. 1995. Maize technology in Malawi: a green revolution in the making? Research Report No. 4. Mexico, DF: CIMMYT. 68 pp.

ICRISAT. 1998. Improvement of pigeonpea in eastern and southern Africa: project completion report. PO Box 39063, Nairobi, Kenya: ICRISAT.

Jones, R.B., Freeman, H.A., Walls, S., and Londner, S.L 1999. Improving the access of small farmers in Africa to global markets through the development of quality standards for pigeonpea. Paper presented at the Workshop on Markets, Rights and Equity: Rethinking Food and Agricultural Standards in a Shrinking World. Institute for Food and Agricultural Standards, Michigan State University, 31 Oct to 3 Nov 1999.

Jones, W.O. 1972. Marketing staple foods in tropical Africa. Ithaca, New York, USA: Cornell University Press.

Le Roi, A. 1997. Evaluation of the situation of pigeonpea production in the semi-arid areas of Kenya. Faculte Universitaire des Sciences Agronomiques de Gembloux. MSc thesis. 75 pp.

Minde, I.J. and Nakhumwa, T.O. 1998. Unrecorded cross-border trade between Malawi and neighboring countries. Technical Paper No. 90. Washington DC, USA: Bureau for Africa, Office of Sustainable Development, Productive Sector Growth and Environment Division, USAID. 48 pp.

Mwale, B., Orr, A., and Saiti, D. 1999. Pests and markets: why farmers grow susceptible varieties of pigeonpea. Farming Systems Integrated Pest Management Project. Mimeo.

Farmer Participation in Evaluation of Improved Pigeonpea Varieties in Eastern Kenya

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Introduction

More than two-thirds and three-fourths of Kenya and Eastern Kenya, respectively, are classified as semi-arid lands (SALs). SALs in Eastern Kenya receive 500-800 mm of rainfall with a distinctly bimodal distribution pattern; the first season from Oct to Dec and the second season from March to May (Braun 1980).

In the wetter SALs, the main crops grown by smallholders are maize, beans, cowpea, and pigeonpea; while in drier SALs, maize, sorghum, pearl millet, cowpea, pigeonpea, and greengram are predominant. Crop productivity is constrained by low and erratic rainfall, inadequate information on improved management practices, insect pests and diseases, and infertile and highly erodable soils (Katumani 1995). Under traditional management practices, maize and beans fail in half the seasons, due low soil moisture and fertility (Stewart and Faught 1984). Even in average seasons, farmers achieve only 25% of yields achieved on research stations. Crop failure results in frequent famines, loss of household income, and hardship for farm families who have to resort to food aid for sustenance.

Pigeonpea is well adapted to semi-arid conditions due to its tolerance to drought and low fertility. More than 95% of pigeonpea production in Kenya is in the SALs of Eastern Kenya. However, the traditional pigeonpea types in these areas are late-maturing (up to 11 months) and are susceptible to fusarium wilt, a devastating disease in SALs. Although local landraces suffer minimal damage by field insects and have good cooking, eating, and marketing qualities, average yields are less than 500 kg ha^{-1} (Omanga et al. 1986).

ICRISAT, in collaboration with the Kenya Agricultural Research Institute (KARI) and the University of Nairobi (UoN), developed short- and medium-duration pigeonpea types that mature in 4-5 and 6-7 months respectively; and long-duration types that mature in 8-10 months. Improved varieties such as Kat 60/8, early to medium-duration, and Kat 777, medium-duration, were selected at KARI-Katumani as promising lines for on-farm testing (Omanga, et. al. 1991). Several improved varieties in different maturity groups were also identified through participatory evaluation, on-station and on-farm, by ICRISAT and its partners (ICRISAT/ADB 1997). These include ICPL 87091 (short duration), ICP 6927, ICEAP 00068 (medium duration), ICEAPs 00020,00040, and 00053 (long duration). Yield estimates of improved pigeonpea on research stations ranged from 1200-2500 kg ha^{-1}.

In on-station experiments, ICEAP 00040 had showed some resistance to fusarium wilt. The short- and medium-duration types, in addition to producing grain earlier than local pigeonpea, give farmers the advantage of two crops in a year, the second being a ratoon crop in the long rains. Furthermore, short-duration varieties offer farmers the flexibility of planting pigeonpea in the long rains.

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However, short- and medium-duration varieties, due to their earliness and/or growth habit, are more susceptible to field insect pests than local pigeonpea (Green et al. 1979). Economic evaluation of researcher-managed trials revealed that chemical pest control by small farmers was profitable on short- and medium-duration but not on long-duration types (ICRISAT/ADB 1998).

Nonetheless, farmers* criteria for selecting improved technologies for trial differ from those of researchers (Collinson 1982). To enhance adoption of these improved varieties by resource-poor farmers, it is critical to ensure participation by a greater number of farmers and their assessment under local circumstances with farmer evaluation. Farmer-managed trials are probably more convincing to farmers than a demonstration plot carefully managed by extensionists, while farmer-to-farmer transfer of improved technologies is well documented (Woolley 1988, Sutherland 1999, Ashby 1985).

Using farmer groups as well as individual farmers in evaluation improves the results and increases the success of both informal and formal methods of technology transfer.

Subsequently, ICRISAT and partners planned and implemented farmer-managed trials, in which all variables (including experimental ones) were implemented by a large number of farmers. Systematic farmer-participatory evaluation was organized in order to determine the potential acceptability to farmers of promising varieties.

The sites chosen were Kionyweni, Thavu, and Karaba, all in Eastern Province but situated in different districts of Machakos, Makueni, and Mbeere, respectively. Although Kionyweni is at a higher altitude and therefore cooler than the other two sites, all three sites have similar rainfall amounts and pattern (Jaetzold and Schimidt 1983). The main difference is that Kionyweni is the least commercialized pigeonpea production area, while Thavu and Karaba have moderate and high levels of pigeonpea trade, respectively.

Objectives

- Determine performance and farmer acceptability of improved pigeonpea production technologies
- Disseminate information on improved pigeonpea production technologies to farmers and extension
- Provide feedback for future research.

Materials and Methods

Farmer-managed trial design

On the basis of PRA studies, action plans for each site were formulated during group discussions with farmers, to carry out farmer-managed trials. Four pigeonpea production technologies (see Table 1) were on offer. Each technology was selected by at least 50 volunteer farmers at each site, making a total of 200 trial farmers at each of the three sites during the 1997/98 cropping season. NPP 670, a well-established improved pigeonpea in Karaba, was used as a control in the short-duration group, while the local pigeonpea was used as a control in the long-duration group. Farmers were provided enough seed to plant at least 625 m^2 of selected varieties.

Table 1. Pigeonpea technologies offered to farmers in Kionyweni, Thavu, and Karaba, Eastern Kenya.

Pigeonpea technology group	Varieties in group
Short-duration in monocrop systems	ICPL 87091, NPP 670
Medium-duration in monocrop systems	Kat 60/8, ICP 6927, ICEAP 00068
Medium-duration in intercrop systems	Kat 60/8, ICP 6927, ICEAP 00068
Long-duration in intercrop systems	ICEAP 00020, ICEAP 00040, ICEAP 00053, Local

In each area, 15 fanners per technology (total 60) were randomly selected for monitoring visits by field enumerators, one at each site. Farmers sowed and managed the trials, and were asked to make observations on grain yield, reaction to field insect pests, maturity period, culinary qualities, seed size, and other important characteristics.

Data collection and analysis

Data from individual farmers were collected from the 15 randomly selected farmers for each technology (there were 4 technologies) at each site. Yields were estimated from a net plot of 25 m^2 for each variety. For each technology, farmers* criteria (desirable pigeonpea qualities/ characteristics) for selecting a variety for trial were established through a 1-10 score system (1 = least important, 10 = most important characteristic) by individual farmers. Further, at each site all improved varieties were evaluated for site-specific desired qualities or characteristics using a scale of 1 = poor, 2 = moderate, 3 = good, 4 = very good.

At crop maturity, three group discussions - one for each of the three duration groups - were organized at each site with at least 30 volunteer farmers in each duration group per site in attendance. During group discussions, pairwise ranking (Theis et. al. 1991) was used to verify farmers* varietal preferences.

Data from individual farmers was inputted in SPSS. Median and Friedman's test statistics (Siegel and Castellan 1988) were used to establish the desired pigeonpea characteristics and preferred varieties, respectively, at each site.

Results

Pigeonpea qualities or characteristics desired by farmers

At all three sites rainfall during the 1997/98 season was influenced by the El Nino phenomenon, during which rainfall was more than 4 times the long-term average. The short-duration group was most severely affected because of the combined effect of higher than normal infestation of pod-sucking bugs and heavy downpours that caused complete loss of the first flush of flowers.

For each technology group, each individual farmer assigned each trait (e.g. large grains) a score on a 1-10 scale where 1 = least and 10 =most important trait. The median test was done for all four technologies to show the fanners' desired pigeonpea qualities or selection

Table 2. Median test results for medium-duration intercrop technology: desirable pigeonpea characteristics in Kionyweni, Thavu, and Karaba, Eastern Kenya.

Desirable characteristic	Median score for desirable characteristic	No. of farmers with score greater than median score			Test of significant difference (p<0.01)
		Kionyweni N=13	Thavu N=15	Karaba N=15	
Adequate fuelwood	0	6	3	0	0.01
Insect tolerance	8	0	1	4	0.20
High yield	7	0	2	15*	0.00
Cooks fast	2	8*	7	0	0.00
Good taste	4	8*	7	1	0.00
Large grains	3	0	0	15*	0.00
Suitable for intercropping	2	5	4	1	0.20
Early maturity	8	2	2	14*	0.00
Green pods peel easily	2	3	7	7	0.84
Wilt tolerance	8	3	15*	0	0.00
Ratoons well	6	5	13*	1	0.00

*** More than 50% of the fanners at that site had scores higher than the median score**

criteria across the three sites. Test results for the medium-duration intercrop technology only are shown on Table 2. A pigeonpea characteristic was considered important at a site if the differences between sites were significant ($p<0.01$) and more than half of the farmers had scores greater than the median score.

Generally, the criteria for selecting an improved variety were consistent in all four technology groups but differed significantly between sites. In Kionyweni, the least commercialized pigeonpea production area, cooking time and taste were important qualities for farmers; while in Karaba, the most commercialized area, farmers rated high yield, large grains, and early maturity as the most important qualities. In Thavu, where pigeonpea commercialization is moderate, wilt tolerance and ratoonability were considered the most important qualities. Moreover, these results were consistent for all four technology groups.

Farmers' varietal preferences

At each site, three group discussions, representing short-, medium- and long-duration pigeonpea types, were held to evaluate farmer preferences for the improved varieties through pair-wise ranking. In addition, a score system (1 = poor, 2 = moderate, 3 = good, 4 = very good) was used by individual farmers to evaluate their preferences for varieties they had tried based only on site-specific desirable pigeonpea characteristics in Table 2. Friedman's test statistic (Siegel and Castellan 1988) was used to establish any significant differences in preference between varieties in each duration group.

Tables 3-5 show the results of individual and group evaluations at the three locations. The mean yield for all varieties in each duration group (short, medium and long) at each site

Table 3. Group and individual farmer evaluation of improved pigeonpea varieties from all three duration groups in Thavu.

Duration group/variety	Mean grain yield (kg ha^{-1})	Mean rank for desired qualities		Overall preference order by individual farmers	Overall preference order by groups of farmers
		Wilt tolerance	Ratoons well		
Short duration (N=15)*					
ICPL 87091	276	1.2**	2.2**	1	1
NPP 670	222	1.8**	1.6**	1	2
Medium duration (N=30)					
Kat 60/8	867	2.0	2.6**	1	1
ICP 6927	803	2.0	2.0**	2	2
ICEAP 00068	833	2.1	1.4**	3	3
Long duration (N=15)					
ICEAP 00020	1493	3.2**	2.5	2	2
ICEAP 00040	2133	3.5**	2.5	1	1
ICEAP 00053	1160	1.5**	2.5	4	4
Local	1245	1.9**	2.5	3	3

* Number of farmers responding under individual assessment
** Friedman's On-square test statistic by duration group was significant at $p \leq 0.01$

Table 4. Group and individual farmer evaluation of improved pigeonpea varieties in the three duration groups in Karaba.

Duration group/variety	Mean grain yield (kg ha^{-1})	Mean rank for desired qualities			Overall preference order by individual farmers	Overall preference order by groups of farmers
		High yield	Early maturity	Large grains		
Short duration (N=15)*						
ICPL 87091	360	1.0**	2.0**	1.0**	2	2
NPP 670	133	2.0**	1.0**	2.0**	1	1
Medium duration (N=30)						
Kat 60/8	627	1.5**	1.0**	1.0**	3	3
ICP 6927	686	3.0**	2.5**	3.0**	1	1
ICEAP 00068	762	1.5**	2.5**	2.0**	2	2
Long duration (N=15)						
ICEAP 00020	1133	2.0	2.0**	2.0**	2	2
ICEAP 00040	1150	3.0	3.0**	3.0**	1	1
ICEAP 00053	na	na	na	na	-	-
Local	na	1.0	1.0**	1.0**	3	3

* Number of respondents or observations under individual assessment
**Friedman's Chi-square test statistic by duration group was significant at $p \leq 0.01$

Table 5. Group and individual farmer evaluation of improved pigeonpea varieties in all three duration groups in Kionyweni.

Duration group/variety	Mean grain yield (kg ha^{-1})	Mean rank for desired qualities		Overall preference order by individual farmers	Overall preference order by groups of farmers
		Taste	Cookability		
Medium duration (N=30)*					
Kat 60/8	653	2.0	2.5	3	3
ICP 6927	975	2.0	2.5	2	2
ICEAP 00068	1075	2.1	2.1	1	1
Long duration (N=15)					
ICEAP 00020	1582	2.3	2.3	3	3
ICEAP 00040	1557	2.8	2.8	1	1
ICEAP 00053	2060	2.3	2.3	3	4
Local	1886	2.8	2.8	1	2

Short-duration varieties (ICPL 87091, NPP 670) were not evaluated due to complete crop failure
* Number of farmers responding under individual assessment
** Friedman's Chi-square test statistic by duration group was significant at $p \leq 0.01$

did not vary significantly. The results of group and individual farmer rankings were similar within a site, but varied across sites.

In Thavu, where the most desirable traits were good ratoonability and wilt resistance, NPP 670 and ICPL 87091 received the same overall rating under individual farmer assessment. However, the latter ratooned significantly better in Thavu, and group evaluation rated it better than NPP 670 (Table 3). Kat 60/8 showed significantly higher ratoonability than ICP 6927 and ICEAP 00068 and was rated the most preferred variety in the medium-duration group by both group and individual farmer evaluation. ICEAP 00040, rated as the best variety, was less susceptible to wilt than the other long-duration types, with ICEAP 00053 being the most susceptible.

In Karaba, where the most desirable traits were high yield, earliness, and large grains, NPP 670, ICP 6927, and ICEAP 00040 were rated as the best varieties in the short-, medium- and long-duration groups, respectively (Table 4). Although NPP 670 was rated significantly higher than ICPL 87091 for yield and grain size, the latter had a significantly higher rating for early maturity. For all desirable traits in Karaba, ICP 6927 and ICEAP 00040 were rated significantly higher than the other varieties in their respective duration groups.

In Kionyweni, where taste and cookability were the most desirable qualities, group and individual farmer evaluation established that ICEAP 00068 and ICEAP 00040 were the best varieties in the medium- and long-duration groups, respectively (Table 5). However, their taste and cookability were not significantly higher than the other varieties in their respective duration groups.

Discussion

Desirable traits and varietal preferences for short- and medium-duration pigeonpea were site-specific as a reflection of local farmer problems, needs, and management abilities. The analysis suggests that with increased commercialization, farmers' preferences become more market-oriented, while in a subsistence production system, preferences are more related to cooking and eating qualities.

In Karaba, about 75% of pigeonpea produced is sold as dry grain or green pods to middlemen who ferry it to Nairobi (Le Roi 1997), and control of field pests is a routine management procedure. Farmers in Karaba required pigeonpea varieties with grain of good marketing quality (bold seeds). Any improved varieties that are high yielding, have bold grains, and mature earlier than local landraces have great potential for adoption. NPP 670 meets these criteria, and has been adopted by 60% of farmers in Karaba (Audi et. al 1999). ICP 6927, an improved medium-duration variety whose grain size is described as large, has the highest potential for wider application in Karaba and together with NPP 670, should be prime targets for a seed multiplication program and official variety release.

Farmers' preferences for early-maturing varieties in Karaba confirm Le Roi's earlier findings that dry grain from early-maturing pigeonpea, often sold before the local pigeonpea comes to market, fetched about twice the price of late-maturing local types. ICPL 87091 was evaluated as significantly earlier maturing than NPP 670, and has a further advantage of producing two crops per year in Karaba. However, grain size of ICPL 87091, described as medium size in varietal descriptors, was evaluated as significantly smaller than that of NPP 670. Therefore, further research should aim at increasing the grain size of ICPL 87091 in order to enhance its use by farmers in market-oriented production areas. We note that scientists at ICRISAT-Nairobi have made crosses between ICPL 87091 and ICEAPs 00040 and 00068 to improve seed size while retaining early maturity.

Pigeonpea grain prices in Machakos district, where Kionyweni is located, are lower than in Mbeere (Mbatia et al. 1991). Furthermore, most trading in pigeonpea is carried out in the local markets and the bulk of grain is bought for local consumption. Because pigeonpea production in Kionyweni is mainly for household consumption, farmers require varieties with good cooking and eating qualities. Farmer selection of ICEAP 00068 and ICEAP 00040 as the most suitable varieties at the location, confirms descriptors that indicate that their cooking and eating qualities are as good as the local pigeonpea. These varieties should be targeted for seed production and official release in Kionyweni and similar areas.

Farmers' preferences for ICPL 87091, Kat 60/8, and ICEAP 00040 in Thavu, Makueni district, may be a reflection of farmers' desire to find solutions to the problems of drought - especially in the long rains - and wilt (Le Roi 1997). Although Kat 60/8 is susceptible to wilt (Omanga et al. 1991) farmers rated it their favorite medium-duration variety due to its good ratooning ability, which enables it to escape terminal drought at the end of long rains. Kat 60/8 and ICPL 87091, with excellent ratooning qualities (according to varietal descriptors), have great potential in Thavu and similar areas with a very short rainfall period during the long rains because the ratoon crop matures early in the season.

However, to further enhance demand for these varieties, some level of wilt tolerance should be incorporated. Farmers evaluation of ICEAP 00053 as having significantly lower wilt resistance than the other long-duration varieties confirms farmer evaluations done earlier in Malawi (ADB 1998, Ritchie et. al. 1998).

Conclusions and Recommendations

The results of farmer participation in evaluation of improved pigeonpea varieties in Eastern Province of Kenya have several policy and research implications. Within the same province, farmers' criteria for selecting improved varieties to try differed in all the three districts. First, this underscores the importance of understanding farmers* selection criteria in the context in which they make decisions, in order to set priorities and strategies for breeding and technology dissemination. Second, the results affirm the importance of farmer input in ensuring the relevance of research products.

In the immediate future, research should focus on incorporating desirable traits that were lacking in the varieties selected by farmers at the three sites. ICRISAT is increasing the seed size of ICPL 87091 from medium to large in order to boost the use of the variety especially in commercialized pigeonpea areas. Incorporating wilt resistance into Kat 60/8 and similar genotypes could boost production tremendously in areas like Makueni, where wilt is a major constraint.

Targeted seed production and distribution by private seed companies of ICPL 87091, Kat 60/8, ICP 6927, NPP 670, and ICEAP 00040 could be initiated to enhance scaling up of production and wider adoption of improved varieties. As the adoption of improved varieties increases, a study to establish diffusion trends for the new varieties in the original trial sites could be carried out in order to provide lessons for further research and policy actions. Concurrently, ICEAP 00040 and ICP 6927 should be officially released, and farmer-managed demonstrations organized to promote and consolidate their use in similar environments.

References

Ashby, J.A. 1986. Methodology for participation of small farmers in design of on-farm trials. Agricultural Administration and Extension 22:1-19.

Ashby, J.A. 1987. The effects of different types of farmer participation on the management of on-farm trials. Agricultural Administration and Extension 25:235-252

Audi, P.O., Jones, R.B., and Tripp, R. 1999. Diffusion and adoption of Nairobi Pigeonpea variety 670 (NPP 670) in Mwea Division of Mbeere District, Eastern Kenya. Pages 38-53 *in* Linking seed producers and consumers: diagnosing constraints in institutional performance in Kenya (Tripp, R., ed). Patancheru 502 324, Andhra Pradesh, India: ODI/ICRISAT

CIMMYT. 1988. From agronomic data to farmer recommendations: an economics training manual. Completely revised edition. Mexico, DF: CIMMYT.

Collinson, M.P. 1882. Farming systems research in Eastern Africa: the experience of CIMMYT and some national agricultural research services, 1976-81. International Development Paper no. 3. East Lansing, Michigan, USA: Michigan State University.

Haugerud, A. and Collinson, M.A. 1990. Plants, genes, people: improving the relevance of plant breeding in Africa. Experimental Agriculture 26:341-362.

ICRISAT/ADB. 1996. Improvement of pigeonpea in Eastern Africa: biannual report, Apr-Sep 1996. PO Box 39063, Nairobi, Kenya: ICRISAT (limited distribution).

ICRISAT/ADB. 1997. Improvement of pigeonpea in Eastern and Southern Africa: progress reports, Apr-Sep 1977 and Oct 1977-March 1998. PO Box 39063, Nairobi, Kenya: ICRISAT (limited distribution).

ICRISAT/ADB. 1997. Improvement of pigeonpea in Eastern Africa: biannual report, Apr-Sep 1997. PO Box 39063, Nairobi, Kenya: ICRISAT (limited distribution).

Jaetzold, R. and Schmidt, H. 1983. Farm management handbook of Kenya. Vol 2, East Kenya. Nairobi, Kenya: Ministry of Agriculture, Kenya, in cooperation with GTZ.

KARI-Katumani. 1996. Priority setting for regional research project: identification of farmer constraints and opportunities in Kionyweni sub-location, Machakos district. Technical Report. Katumani, Kenya: National Dryland Farming Research Centre, KARI-Katumani.

Katumani 1995. Technical Report, KARI-Katumani Regional Research Programme. Katumani, Kenya: National Dryland Farming Research Centre, KARI-Katumani.

Le Roi, A. 1997. Evaluation of the situation of pigeonpea production in semi-arid areas of Kenya. MSc thesis, University of Agronomic Sciences of Gembloux, Belgium.

Mbatia, O.L.E. and Kimani, P.M. 1991. Pigeonpea production and research in Kenya. Pages 118-123 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi (Singh, L., Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Mekbib, F. 1997. Fanner participation in common bean genotype evaluation: the case of Eastern Ethiopia. Experimental Agriculture 33:399-408.

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 (Singh, L., Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Siegel, S. and Castellan, N.J. 1988. Non-parametric statistics for the behavioral sciences (2nd ed). New York, USA: McGraw-Hill.

Sutherland, A.J., Irungu, J.W., Kangara, J., and Muthamia, O. J. 1999. Household food security in semi-arid Africa: the contribution of participatory adaptive research and development to rural livelihoods in Eastern Kenya. Food Policy 24:363-390.

Enhancing Adoption of Pigeonpea in Tanzania Using Participatory Approaches

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Introduction

Pigeonpea is an important grain legume crop in the semi-arid and arid regions of Tanzania. The major production areas are Lindi and Mtwara regions in the Southern Zone and Kilimanjaro and Arusha regions (especially Babati district) in the Northern Zone. The crop is also important as a green vegetable in the Coast, Dar es Salaam, Tanga, and Morogoro regions in the Eastern Zone (Anon. 1999). Pigeonpea is primarily grown for its grain, which is mainly for sale. Only 5-10% of the dry grain is consumed locally. Much of the pigeonpea in Tanzania is grown as an intercrop; mainly with maize and to a lesser extent with sorghum, cassava, and sweet potato (Mbowe and Maingu 1987). For example, 97% of the small-scale farmers in Babati district intercrop pigeonpea with maize (Lyimo et al. 1992).

Pigeonpea marketing began before independence in the 1960s (personal communication, Sheriff Dewji and Sons Ltd., Arusha, Aug 2000). Research and development efforts (on-station and multilocational trials) began in the early 1980s, and farmer-participatory approaches in the early 1990s.

This paper highlights some of the efforts made by the National Agricultural Research System (NARS) in collaboration with farmers and other partners - extension staff, ICRISAT, Kilimo/Sasakawa Global 2000, NGOs, seed producers, farmer associations etc - in order to enhance production and adoption. The activities include diagnostic studies, participatory on-farm research, seed multiplication and marketing, training on improved processing and utilization, and dissemination mechanisms. The paper also shares lessons learned in terms of farmers' preferences for varieties, production constraints, and suggestions from farmers and other stakeholders about what should be done to improve adoption.

Diagnostic and Case Studies

Reconnaissance study on maize/pigeonpea intercropping, Babati and Arumeru

This study was conducted in Babati and Arumeru districts of Arusha region in 1992. The main objectives were to understand the cropping system and the main constraints, in order to plan on-farm trials and address the constraints to help farmers increase pigeonpea

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production. The study revealed that pigeonpea was mainly grown for sale, intercropped with maize; long-duration landraces were grown, with white/cream colored medium-sized seeds or large red/brown seeds. Farmers were ready to increase acreage and production of the crop if reliable marketing channels were established and higher prices offered (Lyimo et al. 1992).

The main production constraints identified were: lack of improved, high-yielding varieties; low prices and lack of assured markets; pests and diseases. Accordingly, research activities have been conducted to address some of these constraints.

Financial profitability of maize/bean intercropping

A study was conducted in 2000 to examine the role of technology in poverty alleviation: specifically, the financial profitability of maize/bean intercropping packages in northern Tanzania. The broad objective was to compare financial returns from three alternative technologies - maize/beans intercropping, maize/pigeonpea intercropping, and maize monocropping.

The study was conducted in Hai, Arumeru, and Babati districts. Farmers were selected from the intermediate and lowland agro-ecological zones in the districts where these three systems are important. Farmers were divided into three categories based on the level of inputs and crop management used. Data on production costs, yields, and output prices were collected through individual and group interviews. Financial returns for each category of farmers were determined using net benefits and sensitivity analysis techniques.

The results (Kirway et al. 2000) indicated that monocropped maize offered lower returns than intercropping: Financial profitability (net benefits) for the two intercrops was similar when 1998 (and earlier) market prices were used. However, market prices for pigeonpea increased sharply in 1999, to 300 TSh kg^{-1}, as a result of marketing efforts by TechnoServe and other partners. At these prices, net benefits from maize/pigeonpea intercropping were almost twice as high as from maize/beans.

Participatory On-Farm Research

Various on-farm research activities have been conducted since the early 1990s (Table 1). They are targeted at the small-scale, resource-poor farmer, and include:

- On-farm evaluation of improved varieties
- Intercropping trials
- Labor-saving technologies
- Pests and diseases
- Farmer assessment of technologies.

On-farm trials of short-duration pigeonpea

Promising short-duration genotypes were verified over several seasons on farmer's fields in nine districts: Kilosa (1995 and 96) and Morogoro (1997,98,99) rural district in Morogoro

Table 1. Progress of efforts to promote pigeonpea adoption in Northern Tanzania, 1989/90 to 1999/00.

Activity	1989/90	1994/95	1999/2000
No. of small-scale farmers participating in on-farm research	-	12	224
Improved varieties known/grown by fanners	-	-	ICEAPs 00020, 00040, 00053, 00068, ICPs 9145, 6927, ICPLs 86105, 87091
Estimated area under improved varieties	-		600
Estimated seed production of improved varieties	-		210-240 tons
Quantity of improved seed sold to small-scale farmers	.		510 kg
Prices offered to farmers (USD kg^{-1})	0.05	0.25	0.45
No. of farmers in farmer producer groups/businesses	-		624
No. of farmers/extension workers trained in processing and utilization	-		300
No. of farmers/extension workers trained in manufacture of cement *chakkis*	-		30
No. of technologies produced (agronomic practices, processing methods etc)	-		4

Sources: Lyimo 1997, interviews with farmers and traders, Aug 2000

region; Handeni (1997), Muheza (1995), and Korogwe (1997, 98, 99) in Tanga region; Kinondoni (1995 and 98), Ilala (1995 and 98), and Temeke (1995,98,99) in Dar es Salaam region; and Same district (1998) in Kilimanjaro region.

Each farmer tested two genotypes, ICPL 87091 and ICPL 86005 (two additional genotypes were tested during the first season in Dar es Salaam, but subsequently dropped based on the 1997 results). Yield performance was variable between genotypes and between districts. In some districts, there were no significant yield differences between genotypes. Farmers were asked to assess the varieties using an open-ended questionnaire and also using matrix ranking. Farmers in all districts consistently preferred ICPL 87091. Based on these results the variety was released in Dec 1999 under the name of Komboa. Farmers considered several traits to be important in a variety - high yield, white seeds, short cooking time, palatability, early maturity, insect resistance, large seeds, synchronous maturity, marketability, and drought resistance.

Medium- and long-duration pigeonpea intercropped with maize

Previous on-station research had identified possible medium- and long-duration varieties suitable for intercropping with maize. To verify their performance and eventually recommend variety(ies), trials were conducted on farmers* fields in Morogoro, Tanga, Coast, Lindi, Kilimanjaro, and Mtwara regions. In 1999, two pigeonpea varieties, long-duration ICEAP 00020 and medium-duration ICEAP 00068, were intercropped with maize variety Staha in Gairo and Mlali divisions in Kilosa and Kongwa districts respectively.

The trials were conducted at two clusters in the two divisions, and implemented by "farmer research groups" (this has proved to be more efficient than the traditional approach involving individual farmers). Soil samples were collected prior to planting in order to establish baseline fertility levels. After harvest, farmers were asked to assess the varieties and the intercropping system using a checklist. Matrix ranking was used to rank the varieties.

At the end of the season, some participating farmers visited Babati district, where maize/pigeonpea intercropping had been adopted. This visit proved very useful - it increased farmers' confidence in the new intercropping system and accelerated adoption. Participating and non-participating farmers requested pigeonpea seed to intercrop with maize during the following season. Among the participating farmers, planted area ranged from 0.6 ha to 1.2 ha per farmer.

Results were not conclusive, with variable yields in the two clusters. However, the trials have clearly increased awareness and adoption of the new intercropping system, and provided useful information on farmers' perceptions of the two varieties (Table 2). These perceptions were also consistent with matrix rankings. Qualities that farmers would like in a pigeonpea variety were insect resistance, large seeds, high yield, marketability, palatability, drought resistance, ease of dehulling, short plant type, white seeds, thick stem, and many seeds per pod.

Medium- and long-duration genotypes were also tested in Lindi, Mtwara, Handeni, Iringa, Morogoro rural, and Same districts in 1998. These included ICP 9145 and 6927, ICEAP 00020, 00040, 00053, and 00068. Additional locations were included this season - Kiegea village in Kilosa district, Mbwewe and Kwaruhombo villages in Bagamoyo district, and Mkata, Mazingara, and Kwachaga villages in Handeni district. In Kiegea village maize/pigeonpea intercropping has been adopted as a commercial crop; pigeonpea is sold to buyers from Dar es Salaam.

Table 2. Farmer's perceptions about suitability of pigeonpea varieties for maize intercropping, Msingisi/Kwipipa and Ihanda in Kilosa and Kongwa districts, 1999.

	ICEAP 00068	ICEAP 00020
Reasons for liking	Early maturing Palatable High yielding Good seed color Short plant Good germination Fast cooking (green) Does not differ much in maturity from maize	High yielding Insect resistant Tall plant (not easily grazed by goats) Multiple harvest Palatable/tasty Fast cooking Large seeds No pod abortion
Reasons for disliking	Susceptible to pests Short plants (easily grazed by goats) Small stem, thus little firewood Pod abortion Flowers when there is rain, hence flower abortion	Late maturing Stays in the field for a long time, danger of being eaten by livestock

Improved medium- and long-duration varieties, Babati and Arumeru

Four long-duration and two medium-duration varieties were evaluated by 50 small-scale farmers in Babati and Arumeru districts in 1997/98. The varieties were ICP 9145, ICEAP 00020,00040, and 00053 (long duration), ICEAP 00068 and ICP 6927 (medium duration). The four long-duration varieties were also evaluated by four farmers in Babati under high fusarium wilt pressure, to compare them with local landraces. All trials were fully managed by farmers themselves.

Due to late delivery of seed, heavy El Nino rains, and poor follow-up of instructions by farmers, no yield data were collected for the fusarium treatments. However, farmers' assessment of the varieties was conducted in Arumeru using matrix ranking and pairwise comparison techniques. The local landrace commonly referred to as Babati White (long-duration, white/cream colored, medium to large seeds) was used as a control. The results (Lyimo at al. 1998) indicated that farmers considered all the test varieties, except ICEAP 00068, to have highly marketable characteristics. Farmers also rated the varieties highly for earliness (except the local and ICEAP 00053) and large seed size. ICEAP 00053 and ICEAP 00068 were rated very low for yield, while ICEAP 00020 and 00040 and ICP 9145 were rated very highly. Based on both matrix rankings and pairwise comparisons, the top three varieties were ICP 9145, ICEAP 00020, and ICEAP 00040. ICEAP 00053 and ICEAP 00068 were the least preferred (Table 3).

In 1998/99 three long-duration varieties, ICEAP 00020,00040 and 00053, were again evaluated on-farm in Babati and Arumeru. ICP 9145 could not be evaluated due to lack of seed. A total of 186 farmers participated in the evaluation. Each farmer was given 1 kg of each variety. Five production clusters were formed in Babati district: four clusters around Babati town (Nangara, Managhat, Singe,and Himiti villages) and the fifth cluster in Dareda area, consisting of farmers from villages around Bacho Training Centre and FARM Africa. One cluster was organized in Arumeru district, with farmers from Kikatiti, Maroroni, and

Table 3. Farmer rankings of varieties and traits, Arumeru district, 1998.

Trait	Variety performance for each trait							Rank
	00068	00040	00020	9145	Local	6927	00053	of trait
Marketability	1	5	5	5	5	' 4	4	1
Time to maturity	5	4	4	4	3	5	2	2
Seed size	4	5	4	4	4	3	3	2
Pest resistance	1	3	4	5	5	2	4	4
Uniform maturity	2	5	5	5	2	2	2	5
Yield	1	4	4	5	2	2	1	6
Total score	13	26	26	28	20	18	17	
Rank of variety (using matrix ranking)	7	2	2	1	4	5	6	
Rank of variety (using pairwise comparisons)	7	3	2	1	4	5	6	

Variety performance on 1-5 scale where 5 = excellent/very good, 4 = good, 3 = average, 2 = satisfactory, 1 = very poor

Table 4. Farmer rankings of varieties and traits, 35 formers in Dareda/Bacho area, Babati district, 1999.

Trait	Variety performance for each trait				Rank
	00020	00040	00053	Local	of trait
Disease resistance	5	5	5	5	1
High yield	5	5	4	5	2
Uniform maturity	5	5	5	4	2
White color	5	5	4	4	4
Taste	4	5	4	5	4
Early maturity	5	5	4	3	6
Pest resistance	4	5	3	5	6
Total score	33	35	29	31	
Rank of variety (using matrix ranking)	2	1	4	3	
Rank of variety (using pairwise comparisons)	3	1	4	2	

Variety performance on 1-5 scale where 5 = excellent/very good, 4 = good, 3 = average, 2 = satisfactory, 1 = very poor

Malula villages. Farmers' assessments of the varieties were conducted using matrix and pairwise rankings (Lyimo et al. 1999).

The main farmer-preference criteria across all clusters were: (i) white color for better marketability, (ii) high yield, (iii) resistance to pests and diseases, (iv) uniform maturity. Based on these criteria and using matrix ranking, ICEAP 00040 and ICEAP 00020 were the most preferred varieties across all sites followed jointly by ICEAP 00053 and the local Babati White (Tables 4-6).

Similar results were obtained with pairwise rankings (Tables 4-6). ICEAP 00040 was the most preferred. The local variety was rated second in Dareda/Bacho and Arumeru in preference to ICEAP 00020 due to its whiter seeds and hectoliter weight. ICEAP 00053 was the least preferred variety across all sites with the exception of areas around Babati town, where it was ranked highest due to its white color, high yield, and uniform maturity.

The evaluations were repeated in the 1999/2000 season using the same sites and approaches. The number of farmers increased to 224.

In addition to providing information on variety performance in relation to farmer preferences, the trials have also helped educate farmers on quality standards for market-oriented production, and encouraged farmers to organize themselves into producer groups to exploit market opportunities.

Insect pest control In malze/pigeonpea intercrop

The trial was conducted in Babati and Arumeru districts in the 1993/94 and 1994/95 seasons. Eight farmers participated in the trial each season. The objectives were to determine the most critical time for control of post-flowering insect pests on pigeonpea, determine the most economical stage for pest control, and monitor the sequence of insect

Table 5. Farmer rankings of varieties and traits, 53 farmers in 4 villages around Babati town, 1999.

Trait	Variety performance for each trait				Rank
	00020	00040	00053	Local	of trait
Early maturity	5	5	5	3	1
	4	5	5	4	1
Disease resistance	5	5	5	2	3
High yield	3	4	5	5	3
White color	3	5	4	4	5
Uniform maturity	3	5	5	3	5
Total score	23	29	29	21	
Rank of variety (using matrix ranking)	3	1	1	4	
Rank of variety (using pairwise comparisons)	4	2	1	3	

Variety performance on 1 - 5 scale where 5 = excellent/very good, 4 = good, 3 = average, 2 = satisfactory, 1 = very poor

pest appearance. Four treatments were applied: (i) unsprayed control (farmers' normal practice), (ii) spray at flowering, (iii) spray at podding, (iv) spray at both flowering and podding stages.

Preliminary results showed that the most important post-flowering insect pests were pod borers (*Helicoverpa armigera, Maruca testulalis).* The farmers' practice (unsprayed) gave the lowest net benefit among treatments. Howeve., data on optimal spray regimes were not conclusive - highest net benefits were obtained from spraying at flowering in 1993/94, and from spraying at both flowering and podding in 1994/95. Results were confounded by

Table 6. Farmer rankings of varieties and traits, 25 farmers at Kikatiti, Arumeru district, 1999.

Trait	Variety performance for each trait				Rank
	00020	00040	00053	Local	of trait
High yield	5	4	4	4	1
White color	3	5	3	5	2
Hectoliter wt.	3	5	3	4	2
Early maturity	4	5	3	3	4
Large grains	4	5	3	3	4
Uniform maturity	4	5	3	2	6
Pest resistance	4	3	2	5	6
Total score	27	32	21	28	
Rank of variety (using matrix ranking)	3	1	4	2	
Rank of variety (using pairwise comparisons)	3	1	4	2	

variety performance on 1 -5 scale where 5 = excellent/very good, 4 = good, 3 = average, 2 = satisfactory, 1 = very poor drought, and no funding was available to continue testing for the third season. Additional trials are needed to develop appropriate spray recommendations to control insect pests.

Maize/pigeonpea intercropping trials in Babati

These trials were conducted in Babati district in 1993/94 and 1994/95. The objectives were to evaluate promising medium- and long-duration varieties for their suitability to intercropping, and determine optimal pigeonpea density for intercropping. Two pigeonpea densities were tested: 55,550 and 27,700 plants ha^{-1}. Three pigeonpea varieties were tested: Kat 60/8, ICPL 87105, and Babati White (local). The maize variety was Kilima (medium duration).

The local pigeonpea outyielded the two improved medium-duration varieties. But it also reduced maize yields in the intercrop, through greater competition. The results indicate that performance of an intercrop depends on multiple factors (e.g. long-duration pigeonpea may need to be planted at lower densities to limit competition with maize), and that local varieties can sometimes outperform "improved" varieties. The highest net benefits were obtained when the local variety was intercropped with maize at a population of 27,700 plants ha^{-1}.

Intra-row spacing in maize/pigeonpea intercrop

Conventional spacings in a maize/pigeonpea intercrop are too narrow to allow the use of ox-drawn weeders. Use of these implements can reduce labor requirements for weeding, a critical constraint in many small-scale farming systems. This trial aimed to evaluate intra-row cropping patterns (i.e. maize and pigeonpea planted within the same row) that provide sufficient space between rows to permit the use of ox-drawn weeding. The trial was conducted in Arumeru district in the 1995/96 (4 farmers) and 1996/97 seasons (8 farmers). Kilimo/SG 2000 supported the trial in 1995/96; while Kilimo/SG 2000 and ICRISAT jointly supported the 1996/97 trial. Three intra-row pigeonpea spacings were tested: (i) 80 x 50 cm (2 plants/hill) with a population of 50,000 plants ha^{-1}, (ii) 80 x 100 cm (2 plants/hill), 25,000 plants ha^{-1}, (iii) 80 x 150 cm (2 plants/hill), 16,600 plants ha^{-1}.

Two strip demonstrations were also conducted alongside the trial. The first demonstration plot had 3 rows of maize followed by 2 rows of pigeonpea. Maize spacing was 80 x 50 cm with 2 plants/hill, population 30,000 plants ha^{-1} Pigeonpea spacing was 80 x 40 cm with 2 plants/hill, population 25,000 plants ha^{-1}. The second demonstration plot had 4 rows of maize followed by 2 rows of pigeonpea. Spacings were the same as in the first demonstration. Plant populations were 33,335 and 20,831 plants ha^{1} for maize and pigeonpea respectively.

Preliminary conclusions were as follows (Lyimo et al. 1997). The time taken to weed 1 acre was 2 hours using oxen, compared to 4-6 mandays using a handhoe. The highest maize and pigeonpea yields were obtained from 3:2 rows of maize: pigeonpea in the demonstration strip trial. However, the highest net benefits and marginal rates of return were obtained from the 80 x 50 cm intra-row planting pattern. The farmers' practice gave the lowest net benefits compared to all other planting patterns.

Matrix ranking of the intra-row planting patterns indicated that farmers prefer the 80 x 50 cm pigeonpea spacing because of higher maize and pigeonpea yields, higher income, and higher production of fodder and fuelwood. Pairwise comparison of all the technologies (intra-row planting patterns as well as strip demonstrations) showed that farmers preferred the intra-row 80 x 50 cm spacing followed by 3:2 rows of maize:pigeonpea.

Demonstrations and Farmer Training on Improved Processing and Utilization

Apart from its potential as a marketable cash crop, pigeonpea can be utilized widely at household level. In order to promote utilization, farmers and extension officers were trained on improved processing and utilization methods. Training was conducted in the following districts - Morogoro rural (1997), Kinondoni, Ilala, Temeke, Korogwe, Arumeru (all in 1998), and Babati (1996, 98 and 99). The training-of-trainers approach was followed. Extension officers at district and village levels and a few farmers were trained to be trainers, and they then trained other farmers under the supervision of researchers. The training covered three methods - processing pigeonpea into *dhal,* how to prepare *dhal* soup, and preparation of *bonkko,* or meal prepared from whole pigeonpea grain. This season, demonstration of these methods will continue at all locations where variety trials are being conducted.

Seed Multiplication and Marketing

In 1995/96 Kilimo/SG 2000, in collaboration with the extension services and Selian Agricultural Research Institute (SARI), initiated seed multiplication groups in Arumeru and Babati districts. Small-scale farmers were organized into groups of 10 farmers each. Every farmer was given 3 kg of Babati White, sufficient to plant 1 acre. After harvest the farmers were asked to give 3 kg to their neighbors who similarly would distribute seed from their harvest to others. Six groups (60 farmers) were involved in the program at the beginning. In 1999/2000 this had grown to 18 groups (180 farmers).

In 1997/98 ICRISAT started contracting farmers and private seed companies to multiply seed of improved varieties both for local distribution and export. Companies such as Rotian Seed Company, Tanzania Plantations, Zanobia Seed, and East Africa Seed have been multiplying pigeonpea seed for the last 2 years. By end 1999, contract farmers in the Northern Zone were growing seed on about 200 acres, producing 70-80 tons of improved seed.

Farmers participating in on-farm trials have also served as seed multipliers. Every such farmer receives 1 kg of seed of the test variety, and we estimate that these farmers can easily produce 80 tons of seed each season.

Efforts are being made by different partners such as ICRISAT, Kilimo/SG 2000, TechnoServe, Rotian Seed Company, Sheriff Dewji and Sons, etc to secure a reliable market and good prices for pigeonpea farmers. One approach is to mobilize farmers into producer and marketing groups or businesses. TechnoServe has already helped establish five businesses - consisting of 200 farmers - in Babati district. Last season the price of pigeonpea rose from the earlier average of 118 TSh kg^{-1} to an average of 300 TSh kg^{-1} (1 US$ = 800 TSh). If the new price remains stable we can expect a large increase in pigeonpea area and productivity.

Dissemination Mechanisms

Various mechanisms are being used to disseminate pigeonpea technologies. Researchers, extension staff and other partners, especially Kilimo/SG 2000, have been organizing field days to increase awareness. These field days are held at both on-farm and on-station trial sites. They have also been organizing visits by policy makers to on-farm trials and demonstrations, helping to strengthen policy support for the crop. Farmers and extension staff work closely together to test technologies on-farm. determine their acceptability and relevance, identify constraints (e.g. through diagnostic studies), and thus create the conditions necessary for rapid adoption. Researchers are preparing posters, leaflets, and other extension materials for technologies that have been tested and found acceptable - agronomic practices, preparation of pigeonpea dishes, and manufacture of cement *chakkis.* Farmer groups are being trained on different aspects of pigeonpea production.

Partnerships are a key factor in technology development and dissemination. Numerous stakeholders are involved in these efforts - farmer groups, TechnoServe and other NGOs, religious groups, Kilimo/SG 2000, ICRISAT, the extension services, private seed companies, and traders. Kilimo/SG 2000 and ICRISAT have been organizing joint annual planning meetings where all key stakeholders are actively involved. As a result of these partnerships, production and adoption of new varieties is increasing in many areas, while market availability and prices paid to farmers have significantly improved.

Lessons Learned

Feedback from farmers and other stakeholders shows that production and adoption of pigeonpea has been constrained by several factors: lack of assured markets and good prices, lack of high-yielding varieties that are also resistant to insect pests and diseases, low input use, poor husbandry practices, lack of knowledge on processing and utilization, and lack of seed of improved varieties.

Production and adoption could improve if these constraints were addressed: for example, through development of markets, provision of credit, and training of farmers in intercropping, pest control, harvesting techniques, and processing and utilization methods.

Accordingly, the national research program will place priority on the following areas:

- Continue with on-farm verification and promotion of improved varieties
- Train farmers in improved crop management practices, train farmers and extension staff in processing and utilization
- Collaborate with other partners to develop markets and increase prices paid to farmers
- Disseminate extension materials for different technologies.

Acknowledgments

We thank the African Development Bank, ICRISAT, Kilimo/SG 2000, Tanzania National Agricultural Research Program, and Farm Level Applied Research Methods for Eastern and Southern Africa (FARMESA) for funding our work. The excellent cooperation received from fellow researchers and technical staff, extension staff, NGOs, and other partners is gratefully acknowledged. No results would have been obtained without the strong support and enthusiasm of farmers at all trial sites, and we thank them for their efforts and for the learning experience.

References

Anonymous. 1999. Proposal for release of short-duration pigeonpea variety Komboa. Submitted to the National Variety Release Committee, Arusha, Dec 1999 (limited distribution).

Kirway, T.N., Ulotu, H.A., Lyimo, S.D., Lema, N.M., Mduruma, Z.O., Semgalawe, Z.M., Akulumuka, V., Mushi, C.S., Rutaihwa, C.E., and Nyaki, A.S. 2000. The role of technology in poverty alleviation: Farm household financial profitability of maize/beans intercropping - a case of Northern Tanzania. Arusha, Tanzania: Department of Research and Development, Ministry of Agriculture and Cooperatives (MoAC); and Entebbe Uganda: Eastern and Central African Program for Agricultural Policy Analysis (ECAPAPA) (limited distribution).

Lyimo, S.D., Foster, M.A., Massawe, F.A., Mollel, N.J., Sulumo, P., Modestus, G., Owenya, M.Z., Mushi, P.P., and Lukumay, N. 1992. Maize/pigeonpea intercropping system in Arumeru and Babati districts, Arusha region: a reconnaissance study report. Arusha, Tanzania: Sasakawa Global 2000.

Lyimo, S.D. 1997. SARI-Kilimo/SG 2000 terminal report for Phase I (1989-96). Arusha, Tanzania: Selian Agricultural Research Institute (limited distribution).

Lyimo, S.D., Massawe, F.A., Owenya, M.Z, Mushi, P.P., and Sulumo, P. 1997. Annual planning meeting report for maize-pigeonpea intra-row intercropping system in Arumeru district, Arusha region in 1997 crop season. Paper presented at the Kilimo/SG 2000 Annual Planning Meeting, Arusha, Tanzania, 3 Oct 1997.

Lyimo, S.D., Massawe, F.A., Owenya, M.Z, Mushi, P.P., and Sulumo, P. 1998. Farmer assessments of pigeonpea varieties in Arumeru district, 1998 crop season. Arusha, Tanzania: Selian Agricultural Research Institute (limited distribution).

Lyimo, S.D., Massawe, F.A., Owenya, M.Z., Mushi, P.P., and Sulumo, P. 1999. Farmer assessments of pigeonpea varieties in Arumeru and Babati districts, 1999 crop season. Arusha, Tanzania: Selian Agricultural Research Institute (limited distribution).

Mbowe, F.F.A. and Maingu, Z.E. 1987. The status of pigeonpea production in Tanzania. Paper presented at the ICRISAT Pigeonpea Scientists Meeting, 2-5 June 1987, Nairobi.

Seed Delivery Systems - Status, Constraints, and Potential in Eastern and Southern Africa

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Introduction

In much of Eastern and Southern Africa agriculture is divided into two distinct sectors; the smallholder sector and the large-scale sector, although the balance between the two varies significantly from country to country. The formal seed sector developed largely in support of large-scale commercial agriculture, with smallholder farmers depending more on informal seed exchange mechanisms. After independence, many governments sought to improve access of smallholders to seed of modern varieties. Formal seed companies were established, largely as state-run enterprises, and were responsible for supplying seed to farmers that was subsidized in one form or another. The bulk of seed supplied through such arrangements was hybrid maize, although seed of small grains was also produced. The process of structural adjustment has seen the liberalization of input and product markets, together with the divestment by governments of state-run seed enterprises.

Private seed companies run along commercial lines have tended to concentrate on hybrid seed production, and on seed of crops that can be sold in large quantities to the commercial farming sector. There is little interest in marketing seed of small grains for a variety of reasons. At prices above the opportunity cost of using own-saved seed, the demand for modern variety seed becomes elastic since few farmers are willing to pay more than a small premium over the cost of saved seed. Transaction costs in seed markets can be unusually high for both buyers and sellers. Farmers encounter the costs of acquiring reliable information about new varieties and they face the risk of buying inappropriate or poor quality seed. Suppliers find it expensive to discover farmers' preferences and their outlays are increased by the inventory, storage, and wastage costs incurred in having to provide multiple varieties of seed in small amounts at the right time; and carrying stocks sufficient to meet uncertain and fluctuating demand (Wiggins and Cromwell 1995). In recent years, a number of private seed companies have emerged specifically to supply the burgeoning relief and development market, as a result of demand from both governments and NGOs.

This paper synthesises the experience from seed research activities in support of the Pigeonpea Improvement Project for Eastern and Southern Africa.

The Nature of Pigeonpea Seed and Seed Quality

Although the floral biology of pigeonpea favors self-pollination, natural outcrossing to the extent of 1 to 70% has been reported (Bhatia et al. 1981, Saxena et al. 1990). With such high

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levels of outcrossing, it would be expected that standard cultivars would become heterogeneous for several important agronomic characters including disease resistance.

In mid-1997, a participatory research assessment conducted by the University of Nairobi (Le Roi et al. 1997) found that the improved pigeonpea variety NPP 670, known locally as Katumani Pigeonpea, was being widely grown in Mwea Division of Mbeere district, and had become an important source of cash for many households in Karaba, Wachoro, and Riakanau sub-locations. The University of Nairobi tested the variety on-farm with one farmer in Wachoro sub-location in 1986. In 1987 the extension services in Mwea purchased seed from this farmer and sold it to other interested farmers in Karaba, Riakanau, and Wachoro. Subsequently, neither the University of Nairobi nor the extension services distributed additional seed. A diffusion study was undertaken to understand how this variety had spread, and whether farmers had difficulty in maintaining varietal purity.

NPP 670 is a determinate cultivar, developed by the University of Nairobi, that matures in 5-6 months (Kimani et al. 1985, Kimani 1991). The plant is easily recognized in the field because of its distinct growth habit, and the seeds are easily identified because of their large size and white color. The study found that the variety had been planted by 79% of farmers at some time, and was being grown by 68% of those interviewed in 1998. In comparison, the most commonly mentioned local varieties, *Githwariga, Kimeru, Kionza,* and *Mwiyumbi,* were known by 44% or less of the farmers.

The most important source of seed for both local pigeonpea and NPP 670 was other farmers, including relatives. This source was more important than markets, shops and extension combined (Table 1). Farmers who obtained seed from other farmers did so mainly within the village rather than from outside. Open-air grain markets were a more important seed source for local pigeonpea varieties (34-47%) than NPP 670 (13-22%), but relatives were more important (17-29%) in first-time acquisition of pigeonpea seed.

Table 1. Sources of local and NPP 670 pigeonpea seed.

	Local variety		NPP 670	
Source of seed	Frequency, first time (%)	Frequency, most recent time (%)	Frequency, first time (%)	Frequency, most recent (%)
Open air market	60 (34)	61 (47)	19 (13)	12 (22)
Other farmers in village	42 (24)	34 (26)	54 (38)	21 (38)
Other farmers outside village	17 (10)	14(11)	23 (16)	12 (22)
Relatives in village	35 (20)	12 (9)	12 (9)	1 (2)
Relatives outside village	16 (9)	6 (5)	5 (4)	2 (4)
Shops	7 (4)	2 (2)	4 (3)	1 (2)
Extension	0	0	19 (13)	5 (9)
Others	0	2 (2)	6 (4)	1 (2)
Total	177(101)	131(102)	142(100)	55(101)

Percentages do not add to 100 due to rounding-up error

Table 2. Quality of NPP 670 seed obtained from different sources.

Source	% of farmers reporting seed as pure, first acquisition	% of farmers reporting seed as pure, second acquisition
Other fanners and relatives	88 (n=94)	72 (n=36)
Market	68 (n=22)	77 (n=13)

Table 3. Percentage of farmers who acquired local and NPP 670 seed from other farmers through purchases (as opposed to free or gift seed) in Karaba, Riakanau, and Wachoro, Eastern Kenya.

	Local pigeonpea		NPP 670	
Sources	First time	Second time	First time	Second time
Other farmers	25	49	77	79
Relatives	5	11	24	33

Farmers were asked about the quality of NPP seed acquired from the most important sources (Table 2). During first time acquisition, farmers relied on other farmers more than the market as a source of pure seed. However, when farmers acquired NPP seed for a second time, there was little difference in quality of seed whether it was acquired from the market or from relatives.

Among the problems associated with informal seed diffusion mechanisms, one frequently cited problem is inferiority of the seed, particularly seed quality. Despite the relatively high level of outcrossing that can occur, seed quality was not a major issue for farmers in this study. Sperling et al. (1996) report similar findings for beans in Rwanda, where the quality of farmer seed compared favorably with that produced under more formal regimes.

Are Farmers Willing to Pay for Seed?

There is a widely held perception that farmers are either unwilling or unable to pay for seed. This is then used to justify the free distribution of relief seed in times of emergency, and to design seed projects where farmers are not expected to pay the very real costs associated with seed multiplication. Table 3 shows the proportion of farmers who acquired local and NPP 670 seed from other farmers through purchases as opposed to free or gift seed. During first time acquisition, most farmers acquired free local pigeonpea seed but purchased NPP seed from other farmers.

During second time acquisition, purchased seed was as important as gift seed for local varieties, whilst almost 80% of farmers who acquired NPP 670 seed from other farmers for a second time, purchased it. A possible reason why the proportion of purchasers was higher in NPP 670 is that this variety is perceived as a cash crop, suggesting that farmers may be willing to purchase seed when there is an assured market.

In 1997, small seed packs of several dryland crops were made available for sale through a network of local stockists in four districts of Eastern Province, Kenya (Omanga et al. 1999). Although this was the first time that stockists had been approached to sell seed, the majority were not only willing to sell seed, but also to pay for the seed on delivery, which suggests they were confident that there was a ready market. When follow-up visits were made to stockists, most requested more seed to sell. The exercise was repeated in 1999, with similar results.

The results from the NPP 670 adoption study and the marketing of small seed packs suggest that demand for seed is higher than supply; and that this deficit could potentially be met by the formal seed sector. It is simplistic to conclude that farmers are unwilling to pay for seed when they have never had the opportunity to purchase seed, but we should also recognize that the type of crop and the ease with which farmers can save their own seed will affect demand. Pigeonpea has a relatively high seed multiplication rate, and farmers have little difficulty storing the crop - both factors are likely to reduce the demand for purchased seed. In contrast, *Phaseolus* beans are being supplied by commercial seed companies in Kenya, probably because beans are planted at a higher seed rate, and the risk of crop loss is higher in semi-arid districts.

Stimulating Demand for Seed

Farmers are hungry for information, but the technology dissemination process is flawed. How does information about modern variety seed reach farmers? For optimum performance, modern variety seed often requires the use of additional inputs or some modified management practice. The formal seed sector has a vested interest in ensuring that this information reaches farmers, but the flow of information in the informal sector is less structured. The results from the NPP 670 study found that 75% of farmers growing NPP 670, first learnt about the variety from seeing it in the field, and the remaining 25% first heard about it (Table 4). Although extension played a role in the dissemination of information, by far the most important medium was visual observation of the crop being

Table 4. Sources of information on NPP 670 pigeonpea.

	Learning method (%)	
Source of information	Hearing	Seeing
Farmer in village	19 (44)	68 (53)
Farmer outside village	3 (7)	43 (34)
Relative in village	0	8 (6)
Relative outside village	0	3 (2)
Extension	21 (49)	6 (5)
Total	43(100)	128(100)
Percentage by learning method	25	75

grown by other farmers in the village. Once farmers had been exposed to the crop, the majority of them (69%) started growing it the following season. There was no association between how farmers first learnt about the crop and the time taken before they first grew it themselves (Audi et al. 1999). The message is clear - to create demand for modern variety seed a well organized marketing campaign is needed, to ensure that as many farmers as possible are exposed to the seed. If farmers like the variety, demand for more seed will be created - which means that a system is needed to meet the created demand.

Developing Vertical Linkages

Although results from the NPP 670 and small seed pack studies suggest that there is a commercial demand for seed, we need to consider ways in which this could be strengthened. Jones et al. (elsewhere in these proceedings) have described a process of technology exchange based on the development of strategic partnerships. This can as well be applied to the seed sector.

Input and output markets serve farmers best when there is some degree of vertical coordination among input distribution, output marketing, and credit functions, which lowers costs and improves loan repayment rates (Kelly et al. 2000). In Mozambique the cotton sector provides a good example of this, while in Malawi the tobacco industry illustrates the types of arrangements that exist. Pigeonpea, being both a food and a cash crop, presents an opportunity to develop some degree of vertical coordination between input distribution and output marketing. Three pilot initiatives have been undertaken - in Mozambique, Malawi, and Tanzania- that will be described to illustrate the type of arrangements that are being considered.

In Mozambique, TechnoServe identified a market opportunity in India for up to 100,000 t of pigeonpea provided deliveries are made from May to Sep. As a result of consolidation in the *dhal* processing industry in India, a number of large-scale processors have emerged who are short of product to process in the period leading up to the start of the Indian harvest. Rather than maintaining expensive inventories, they were invited to Mozambique (with support from TechnoServe) to look at the potential for sourcing pigeonpea from several of the cotton companies who work with networks of growers through a system of cotton concessions controlled by the Mozambique government. The buyers were shown samples of several improved short-duration pigeonpea varieties developed by ICRISAT, which had been tested in Mozambique. ICPL 87091 was selected because it was similar to the Indian product, and could therefore be easily accommodated by the existing processing equipment. As the cotton companies are in a position to deliver improved seed to the farmer network, they are now taking responsibility for seed production to ensure that quality seed of the right variety is available to farmers on time. In this example, there is a strong incentive for farmers to purchase seed of the short-duration variety which will allow them to benefit from the higher prices paid in India for pigeonpea delivered between May and Sep. However, there is a possibility that once farmers have seed of this variety, they will revert to saving their own seed. Both TechnoServe and the cotton companies are aware that if the quality of the pigeonpea they supply declines, they risk getting paid a lower price, and losing the market For this reason, a brand (Nacala Gold) has been developed with clearly defined quality standards. Producers that do not meet these standards will not be allowed to market under this brand, which aims to attract a price premium.

Malawi has the largest pigeonpea processing industry in Africa, with an installed capacity to process approximately 20,000 t of *dhal* per annum from 10 mills. The requirements of the Malawi industry are somewhat different to that of Mozambique. Pigeonpea is grown by smallholder farmers in the southern region. The dominant planting system is to intercrop long-duration varieties with maize at the start of the rainy season. Harvest of dry pigeonpea starts in Aug, although green pigeonpea, primarily for home consumption, is harvested from July onwards. Malawian traders have a small window of opportunity to export unprocessed pigeonpea to India before the price declines, after which the Malawi product is no longer competitive due to high transport costs. However, the crop continues to find a market as domestic processors then stockpile the crop for processing into *dhal* over the coming months. Malawian pigeonpea used to fetch a premium in the Indian market because of the bold, cream-colored seeds. The product was targeted at a few specialized processors who had the machinery to handle the relatively large grains. Malawi *dhal* was also well known in the demanding European market, and was treated as the benchmark against which other *dhals* were compared. Because of declining quality standards, Malawi pigeonpea no longer fetches a premium, and processors have also had to source increasingly large amounts of their crop from Mozambique due to production shortfalls within Malawi itself. To reverse the decline in production and quality, processors have established the Grain Legume Development Association Limited (GLDAL). Recognizing that one major cause of low grain legume productivity is lack of quality seed, GLDAL has undertaken a pigeonpea seed multiplication program for a wilt-resistant variety with bold, cream-colored seed, with the support and expertise of government and ICRISAT.

The Mozambique and Malawi examples illustrate how closer vertical coordination between input distribution and output marketing can stimulate commercial investment in seed supply. One factor that is becoming increasingly apparent in the development of these strategic partnerships is the high transaction costs. These are discussed by Freeman and Jones elsewhere in these proceedings.

Seed Policy

Throughout Eastern and Southern Africa, seed policies have been developed to regulate the formal seed sector. These policies address two major issues; the types of crop varieties that can be grown, and seed quality. In Kenya for example, the Seeds and Plant Varieties Act (Laws of Kenya 1991) states that "an application for the inclusion of a plant variety in the appropriate section of the Index after it has come into force shall be granted only... "when the agro-ecological value surpasses that of the existing ones in some aspect according to the results in official tests."

Commercial crop production usually consists of monocropped areas of a single crop variety. In marked contrast, smallholder farmers tend to grow a mixture of crops and varieties. In three sub-locations of Mbeere district, more than 20 local pigeonpea landraces were identified, and when the modern variety NPP 670 was introduced, it was added to the existing portfolio of varieties grown (Jones et al., these proceedings). In Sudan, farmers could name at least 10 local sorghum landraces, with many farmers planting all 10 in the same field. Each landrace was planted because it addressed a specific need such as the provision of sweet stems for chewing early in the season, or was known to perform well when planted in a specific agro-ecological niche in the farm. Seed policies designed to ensure that only well adapted and productive varieties enter the formal seed sector, work against the needs of smallholder farmers who utilize varietal mixtures for good reason.

The formal seed sector has been reluctant to push for the release of modern varieties because of the expense involved, and the lack of clearly defined evaluation criteria. On-farm trials with seven modern pigeonpea varieties in three sub-locations of Eastern Province, Kenya, over the period 1997-99 found that farmers in each sub-location ranked the varieties differently. This result highlights the very different needs of smallholder farmers, and the difficulties involved in discovering farmer preferences (see Audi and Jones, these proceedings).

Related to farmer preference is the issue of end-user needs. Where an identified market exists, farmers need to have the flexibility to grow a variety that is demanded by the market even if the agro-ecological value does not surpass that of an existing variety.

Plant breeding is expensive. Increasingly, modern varieties developed in one country can be used in countries with similar agro-ecological zones, and yet seed policies dictate that the whole testing procedure needs to be repeated. There are moves to harmonize seed laws to avoid unnecessary repetition, but in the meantime the losers are smallholder farmers who are denied access to modern variety seed that could potentially play an important role in the farming system.

Seed Production

Three distinct categories of seed are recognized, breeder, foundation (also referred to as basic seed), and certified seed. This paper will avoid any lengthy discussion on technical aspects of seed production. Rather, attention will be focused on the necessity to clearly define the roles and responsibilities of different organizations in the seed production chain to ensure the production of quality seed.

Breeder and foundation seed

Breeder seed is produced in small quantities under close supervision, while certified seed production is done on a much more extensive basis under less intensive supervision. Foundation or basic seed production is an intermediate step between breeder and certified seed. Failure to produce quality breeder seed will affect the subsequent quality of foundation and certified seed.

All pigeonpea research in sub-Saharan Africa to date has been publicly funded through national agricultural research systems, including universities. Many of these programs have made use of germplasm from ICRISAT and elsewhere, and there have been official releases of improved pigeonpea varieties in at least four countries in the region. Although considerable progress has been made, there are serious deficiencies in the mechanisms to ensure the sustainable supply of breeder and foundation seed. Two initiatives have been started to improve the availability of breeder and foundation seed that will be described; one in Kenya and one in Malawi.

The Kenya Seed Unit was established under the Kenya Agricultural Research Institute (KARI) in 1997 with the primary objective of producing foundation seed of dryland crops for sale to private seed firms and development projects (Omanga 1999). The sale of foundation seed is accompanied by a document from the Kenya Seed Unit authenticating the material being supplied. This document needs to be produced before the Kenya Plant Health Inspectorate Service (KEPHIS) will undertake seed certification. The price of foundation seed has been set to ensure that the unit will be self-sustaining in the long term. The seed unit contracts plant breeders to produce breeder seed, and KEPHIS also charges to undertake seed certification.

In Malawi, the United States Agency for International Development (USAID) has funded ICRISAT to establish a revolving fund for foundation seed production of groundnut and pigeonpea. This project has only been established for one year, but already significant quantities of foundation seed have been multiplied that can now be supplied to NGOs and other parties interested in undertaking certified seed multiplication.

It is too early to evaluate the long-term success of these initiatives in improving the supply of quality seed to farmers. It is clear that the establishment of such institutions will require that the price charged for seed reflects the not insignificant costs that are incurred to ensure a steady flow of quality breeder and foundation seed.

Certified seed

Production of certified pigeonpea seed by the formal seed sector has only just started in Eastern and Southern Africa. In Tanzania, Rotian Seed Company is multiplying ICEAP 00040 which will be supplied to farmers in Babati district. These farmers are being contracted to produce grain for a UK buyer who requires 2000 t of bold, cream-colored grain. In Kenya, Western Seed Company is multiplying Kat 60/8 and ICPL 87091 under contract to the GTZ-funded Integrated Food Security Project/Eastern, and for sale to farmers in small packs. In 1998 and 1999, KARI and ICRISAT marketed small seed packs of pigeonpea and other dryland crops to farmers through selected stockists in four districts of Eastern Province.

Discussion

This paper has attempted to argue that the development of sustainable seed delivery systems for small grains such as pigeonpea will require much closer collaboration between a range of partners including both public research and the private sector. The majority of seed initiatives for small grains in sub-Saharan Africa focus on increasing seed supply, rather than on creating demand for improved seed. So long as there is funding for such initiatives, there is the possibility of introducing seed of improved varieties, but the impact from such schemes is relatively small because of the substantial costs involved. There is evidence that the injection of small amounts of improved seed can lead to wide-scale diffusion through the informal seed sector. However, because there is a significant degree of outcrossing in pigeonpea, improved cultivars tend to become heterogeneous over time, thus losing some of their good attributes. Far greater impact will be achieved if vertical coordination between input distribution and output marketing can be achieved. In such arrangements, seed supply responsibilities will be taken over by the private seed sector, based on clear market incentives.

Acknowledgments

We gratefully acknowledge the support of the African Development Bank in funding the Project for the Improvement of Pigeonpea in Eastern and Southern Africa, through which much of the work described was funded. I would also like to thank my ICRISAT colleagues in Nairobi, and Rob Tripp of the Overseas Development Institute for his insightful ideas on seed issues.

References

Audi, P., Jones, R., and Tripp, R. 1999. Diffusion and adoption of NPP 670 in Mwea Division of Mbeere district, Eastern Province, Kenya. Pages 38-53 *in* Linking seed producers and consumers: diagnosing constraints in institutional performance - Kenya. PO Box 776, Bulawayo, Zimbabwe: ODI/ICRISAT.

Bhatia, G.K., Gupta, S.C., Green, J. M., and Sharma, D. 1981. Estimates of natural cross-pollination in *Cajanus cajan* (L) Millsp: several experimental approaches. Pages 129-136 *in* Vol. 1, Proceedings of the International Workshop on Pigeonpeas, 15-18 Dec 1980, Hyderabad. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Kelly, V.A., Crawford, E.W., Howard, J.A., Jayne, T., Staatz, J., and Weber, M.T. 2000 Towards a strategy for improving agricultural inputs markets in Africa. Policy Synthesis No. 43. East Lansing, Michigan, USA: Michigan State University.

Kimani, P.M. 1991. Pigeonpea improvement research in Kenya: an overview. Pages 108-117 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop (Singh, Laxman, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL Program, ICRISAT.

Kimani, P.M., Okiror, M.A., and Sikinyi, E.O. 1985 Second progress report for the Pigeonpea Project, Phase III. Ottawa, Canada: International Development Research Centre.

Laws of Kenya. 1991. Seeds and Plant Varieties Act, Chapter 326, 1977, revised edition 1991. Nairobi, Kenya: Government Printer. 96 pp.

Le Roi, A. 1997. Evaluation of the situation of pigeonpea production in the semi-arid areas of Kenya. Faculte Universitaire des Sciences Agronomiques de Gembloux, Belgium. MSc thesis. 75 pp.

Omanga, PA. 1999. Source seed supply: current status of breeder and foundation seed supply for pearl millet, sorghum, groundnut and pigeonpea. Pages 74-84 *in* Linking seed producers and consumers: diagnosing constraints in institutional performance - Kenya. PO Box 776, Bulawayo, Zimbabwe: ODI/ICRISAT.

Omanga, P.G.A., Jones, R.B., and Audi, P.O. 1999. Preliminary experiences from test marketing of small seed-packs in Machakos, Mbeere, Makueni and Mwingi Districts, Eastern Province, Kenya. Pages 54-62 *in* Linking seed producers and consumers: diagnosing constraints in institutional performance - Kenya. PO Box 776, Bulawayo, Zimbabwe: ODI/ICRISAT.

Saxena, K.B., Singh, L., and Gupta, M.D. 1990. Variation of natural outcrossing in pigeonpea. Euphytica 46:143-148.

Sperling, L., Scheidegger, U., and Buruchara, R. 1996. Designing seed systems with small farmers: principles derived from bean research in the great lakes region of Africa. ODI Agricultural Research and Extension Network Paper No. 66. London, UK: Overseas Development Institute.

Wiggins, S. and Cromwell, E. 1995. NGOs and seed provision to smallholders in developing countries. World Development 23:413-422.

Achieving Impact, through Partnership, in the Livelihoods of People Living in Extreme Poverty

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Introduction

Partnership is a misunderstood and abused term in agricultural development. Many partnerships are no more than "arranged marriages'' that satisfy donor requirements for funding. This paper will differentiate between "paper" partnerships and substantive partnerships where all partners work together to achieve a common goal. The concepts of stakeholders, networks, and ultimate and intermediate customers will be discussed in relationship to partnership.

Partnership for agricultural development is needed for the following reasons:

- Increases both the scale and the scope of activities
- Increases cost effectiveness
- Creates a demand for services
- Increases accountability
- Ensures a pathway from development to promotion and exploitation of research results
- Increases the likelihood of impacting on the livelihoods of the rural poor.

Increasingly, donors supporting agricultural research are insisting that funded activities achieve significant and cost-effective impact at the farm level. Too often in the past, research has been carried out, analyzed, published, and disseminated to a small audience of fellow researchers. The impact has been on the collective research body of knowledge and not on productivity gains and profitability at farm level.

Elements of Effective Partnership

Effective research-NGO partnership creates a demand for research services and increases the accountability of both research and development partners. The following are required for an effective partnership:

- Common goal
- Common strategy
- Shared commitment
- Recognized complementarity
- Transparency.

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Common goal

The goal, shared by research and NGO partners, should be the following: *Achieving a significant, sustainable, and equitable impact on the livelihoods of people living in extreme poverty.*

This is an accepted goal of Catholic Relief Services and of most NGOs. Increasingly, it is the goal of donor agencies, regardless of whether it is research or development being funded. In fact, it is the stated goal in a recent call for project proposals from the Department for International Development, UK (DFID 2000). And more recently, it has become a stated goal of many national and international research institutions. For example, ICRISAT states that the release of 22 sorghum and 11 pearl millet varieties in the past 10 years is not sufficient - there must be impact on reducing hunger and creating an economic surplus (ICRISAT 1997).

Implicit in a shared goal is concurrence that "people living in extreme poverty" are the ultimate beneficiaries served by the partnership.

Common strategy

The common strategy needs to be based on the acceptance that impacting on livelihood security is complex and that a multi-institutional approach is needed. There are two important parts of this acceptance: (i) recognition that an independent strategy is inadequate, (ii) recognition that other institutions are needed to complement one's own activities. NGOs, especially well-funded ones, are often complacent. A recent article by White and Eicher (1999) was directed at this complacency.

- The expansion of NGO activities in Africa's agricultural development has not been based on solid and impartial evidence of their performance ...
- NGOs have moved far beyond their traditional role as purveyors of disaster relief...
- A growing number of commentators have pointed out a wide range of constraints to NGO performance and have raised the possibility that NGOs may in fact be less equipped to handle some of the complex tasks of agricultural development...

The comment that the traditional role of NGOs is as "purveyors of disaster relief" is interesting. Though true for CRS, it is certainly not the case for the vast majority of NGOs working in Africa. CRS is actively engaged in both agricultural recovery and agricultural development. Rather than criticizing NGOs for transitioning from relief to development, it would be better to encourage research institutions to become more active in assisting communities recover from disasters, both natural and civil. (For example, ICRISAT is collaborating with CRS and ODI on a seed aid and seed security study in northern Uganda and southern Sudan.) Though the statements of White and Eicher are perhaps excessively provocative, it is essential for NGOs to realize that they are not equipped to handle all of the complex tasks in agricultural recovery and development.

Agricultural research institutions need to also realize that they too are not equipped to handle all tasks. The World Bank is finally abandoning the Training & Visit system of agricultural extension in Africa, farmer adoption of new technologies has been disappointing in Africa, and donor support to both the International Agricultural Research Centers (IARCs) and the national agricultural research systems (NARS) for on-station research continues to decline. The fact is that the 22 sorghum and 11 millet varieties developed by ICRISAT and released in Eastern and Southern Africa have not been adopted by many farmers and there has been no significant impact on reducing hunger and increasing incomes. Partnership comes from a perceived need and the belief that another can fill that need. NGOs, IARCs, and NARS need each other to achieve a significant, sustainable and equitable impact on farm families living in poverty.

Shared commitment

USAID (1995) defines a partner as an "organization or customer representative with which/whom USAID collaborates to achieve mutually agreed objectives and to secure customer participation." As defined by USAID, partnership is more than a bilateral relationship. It encompasses the concept of "stakeholders." USAID defines stakeholders as "parties whose support or acquiescence is necessary to achieve goals." An effective partnership is more substantive than a network or stakeholder consultation. An effective partnership is the result of a shared commitment between individuals and between institutions. Within partner institutions, different individuals play different roles.

Responsibility. The foundation of a partnership is an equal sharing of responsibilities between individuals representing their institutions. Responsibilities should be included in respective terms of reference and the performance of the partnership should be part of the evaluations of the individuals responsible for the partnership.

Authority. The support of Program and Executive Directors of both institutions is essential to an effective and durable partnership. Without this support, a partnership will tend to focus more on satisfying a donor requirement than on achieving a shared goal. Partnerships based on expediency always fail.

Support and consultation. A partnership requires consultation with and the support of staff of both organizations. Partnerships reflect the complexity of achieving a shared goal. If a partnership is based on a perception of the need and a recognition that another can complement one's own strengths, then this requires broad institutional support.

This requires that all institutional stakeholders are involved in the process and in the partnership. Partners should be involved in each other's strategic planning. For example, the foundation of the CRS-ICRISAT partnership on chickpea promotion was ICRISAT's participation in the CRS/Tanzania strategic planning process.

Communication. The best indication of a "paper" partnership is lack of knowledge of the relevant activities of the other partner. There must a continuous process of consulting and informing. In addition to intra-partnership communication, the partnership should also be publicized so that it is recognized and understood both inside and outside the concerned institutions.

Capacity and funding complementarity

Both ICRISAT and Catholic Relief Services focus on the farming systems of the semi-arid tropics in Africa. CRS is an integral part of a large and effective agricultural relief and development network working in 33 countries in sub-Saharan Africa. CRS always works through local implementing partners in assisting the most vulnerable communities to alleviate poverty and achieve social justice. ICRISAT supports agricultural development with knowledge, skills, and technologies with the objectives of improving crop productivity and food security and reducing poverty. ICRISAT forms partnerships with government, NGO, and private sector organizations.

When a research institution partners with an NGO, it must recognize that the NGO, working through local NGOs and community-based groups, can effectively increase the geographic scope and scale of a project. When an NGO partners with a research institution, it must recognize that research has the capacity and network in developing and adapting technologies for smallholder farmers. With complementary skills, both partners participate in the testing and exchange of technologies with participating farmers and communities.

In addition to complementary capacities, research institutes and NGOs often tap different donor bases. Partnerships can attract funding in three ways:

- Greater use of sub-grants to fund adaptive research activities in an NGO project or fund outreach/extension activities in a research project
- Development of joint proposals
- Leveraging of different donor sources.

Importance of transparency

Partnership is a flexible process and not a static product. A partnership evolves with time, changes in personnel and leadership, and a change in both development needs and opportunities. This requires transparency to maintain trust and confidence.

Recommendations for Building a Sustainable Partnership

The recent partnership experience between ICRISAT/Nairobi and CRS/East Africa has resulted in four recommendations:

1. Be patient - build confidence gradually
   A partnership must be built slowly and incrementally. The initial milestones need to be realistic.
2. Invest time and money up front
   It is unrealistic and even unwise to begin a partnership with external funds. Rather, invest own resources initially.
3. Be flexible and willing to compromise
   Working in partnership is always more challenging than working alone. Priorities are never synchronous.

4. Do not assume the partner will carry out certain tasks

   The partnership should never be taken for granted. Even with solid institutional support behind a partnership, its sustainability remains the responsibility of individuals.

Outcomes of a Successful Partnership

The ICRISAT/Nairobi and CRS/East Africa partnership is 2 years old. It has already resulted in the following outcomes.

Chickpea promotion on black cotton soils in East Africa

CRS opened a field office in the Lake Zone of northern Tanzania in 1997. During preliminary agricultural assessments, CRS learned that chickpea had potential as a cash crop and that ICRISAT had collaborated with the Tanzania Agricultural Research Organisation in carrying out chickpea variety trials. Without an identified client for the chickpea research, there was no follow up until CRS-ICRISAT partnership developed a joint strategy to promote chickpea as a market-oriented crop for food-insecure farm families in Mwanza and Shinyanga districts. On-station trials have now resumed and on-farm work is planned for 2001.

Strengthening seed systems for agricultural recovery

CRS carries out "seeds and tools" programs for agricultural recovery throughout East Africa. CRS/East Africa submitted a proposal to USAID/Office of Foreign Disaster Administration to assess current seed aid activities in the region. CRS invited ICRISAT/Nairobi and the Overseas Development Institute (ODI) to partner in the proposal; and ICRISAT eventually became the lead agency in the project, which was funded in late 1998.

This partnership is contributing to an understanding of seed systems and seed aid in Eastern and Southern Africa, and particularly the past and potential roles of CRS and ICRISAT. In the future, the partnership will be more proactive in intervening earlier in the disaster cycle and employing better diagnostic tools to assess the problem and determine recovery strategies.

Development of an East Africa grain legume strategy

Prior to the partnership with ICRISAT, CRS/East Africa relied on local communities and implementing partners to determine the focus of its agricultural development projects. The resulting projects tended to focus on environmental sustainability and subsistence crops. Without a market approach, most CRS activities failed to achieve significant impact. The development of a Regional Grain Legume Strategy, with support from ICRISAT, has led CRS to adopt a market approach and to focus on high value grain legumes such as pigeonpea, chickpea, groundnut, and cowpea.

Integrated watershed approach

CRS has a long history of food-assisted sustainable agriculture development. As one of the largest USAID/Food for Peace Cooperating Sponsors, CRS uses food aid as a resource for agricultural recovery and development in Food for Work projects. CRS currently programs food aid into watershed development in Ethiopia, Kenya, Uganda, and Rwanda. Given the complexity of a watershed, with different landscape units requiring different interventions, and the importance of measuring impact, CRS and ICRISAT-Ethiopia have begun collaborating on a joint project in the Amhara region of Ethiopia. If the results are positive, CRS intends to request ICRISAT assistance in watershed planning in Kenya, Rwanda, and Tanzania as well.

Pigeonpea crop protection

Pigeonpea is susceptible to a range of insect pests, and without effective pest management, yields are disappointing. CRS and ICRISAT agree that a long-term crop protection strategy must combine on-station research with farmer-managed research and intensive farmer training in pest monitoring and in safe and effective use of insecticides. DFID recognizes that both research and promotion are needed in order to increase the incomes of poor farmers; and has expressed an interest in funding a CRS-ICRISAT-NRI partnership in pigeonpea crop protection in Kenya and Tanzania.

Sesame promotion

With a focus on the semi-arid tropics and with a market approach, CRS identified sesame as a potential cash crop in eastern and western Kenya, southern Sudan, northern Tanzania, and northern Uganda. Farmers in these four countries currently cultivate sesame primarily as a food crop, using traditional varieties. Currendy sesame research and development is moribund in Eastern Africa, with 5000 accessions residing in the Kenya genebank. Though sesame is not one of its mandate crops, ICRISAT has agreed to support CRS by rejuvenating and evaluating the materials in the genebank and identifying high-quality, high-yielding sesame varieties.

Conclusion

Though not yet 2 years old, the CRS-ICRISAT partnership in Eastern Africa is promising. This partnership emerged from a mutual realization that agricultural development is complex; and that no one organization alone can achieve significant, sustainable, and equitable impact on the livelihoods of the rural poor. It must be emphasized that effective partnership is also complex. Successful and sustainable partnership requires planning and management. It requires a shared goal, strong support of management, clearly articulated objectives, commitment of staff, continuous monitoring, and periodic evaluation.

References

DFID (Department for International Development) 2000. DFID Crop Protection Progamme: call for proposals. London, UK: DFID (limited distribution).

ICRISAT. 1997. Southern and Eastern Africa Region Highlights 1996. PO Box 776, Bulawayo, Zimbabwe: ICRISAT.

USAID (United States Agency for International Development). 1995. Customer service planning: re-engineering transition. Guidance Cable No. 5. Washington DC, USA: USAID.

White, R. and Eicher, C.K. 1999. NGOs and the African farmer: a skeptical perspective. Staff Paper no. 99-01. East Lansing, Michigan, USA: Dept of Agricultural Economics, Michigan State University.

Discussions - Technology Exchange

Farmer-participatory research

Many earlier technologies have remained on the shelf because they were developed without farmer participation. Some scientists felt farmers were ignorant, and did not consider their needs and priorities in the technology development process. In fact, farmers have a clear idea of what they want, and technologies that do not address these needs have little chance of being adopted. Farmer-participatory research approaches are gradually becoming more widely used, and this must continue.

Two factors must be considered in such research - "hidden" or "unfelt" needs, and wrong perceptions. Farmers may not be aware of a problem because its effects are dispersed or occur very slowly; or their views on a new technology may be influenced by wrong perceptions and lack of information. These problems can be addressed by researchers working closely with farmers.

Sustainability of NGO operations

In many cases, NGOs have provided free seed, grain, or other facilities through disaster relief programs. Many of these programs have tended to become institutionalized, with interventions in most seasons. As a result, local communities throughout Eastern and Southern Africa are becoming dependent on external assistance. Such hand-outs are not sustainable, and slow down - rather than accelerate - development. Rather, the goal should be development of the private sector, i.e. encouraging farmers to purchase inputs rather than depending on free assistance.

Having said this, it must be noted that relief programs are generally led by governments, not NGOs - governments are equally to blame for encouraging communities to become donor-dependent. Another factor is that governments are simply not active in areas of civil disaster, where the needs may be the most urgent (e.g. during 15 years of civil war in Uganda). In these circumstances NGOs are the only organizations able and willing to provide assistance.

Partnerships and comparative advantages

Partners must be selected after considering comparative advantages. For example, NARS may have technical skills but no funds, while ICRISAT and some NGOs can access funds for programs with a clear plan of work and good synergies. Some NGOs such as Catholic Relief Services and World Vision have trained agriculturists on their staff, and are able to plan and implement technically sound programs. TechnoServe has unique expertise in business development, which can complement other organizations' skills in institution-building at grassroots level. Thus, a number of organizations are available, and interested in pigeonpea development, with complementary skills. We must be careful in selecting

Effect of Genotype, Storage Temperature, Shelling, and Duration of Storage on Quality of Vegetable Pigeonpea

M C Onyango[1] and S N Silim[2]

Introduction

Unconfirmed reports indicate that Kenyan-grown green peas (immature pigeonpea and garden pea seeds) are more susceptible to wilting, i.e. loss of moisture during storage. The desiccation which results from moisture loss adversely affects the appearance, texture, flavor, and saleability of produce. Moisture loss also leads to reduction in nutritional quality (Wills et al. 1981). Different genotypes of various vegetables have been shown to differ in the rate of deterioration as a result of wilting (Kays 1991).

One way of reducing moisture loss in produce is by proper handling, for example storing and transporting them in low-temperature conditions. In some vegetables such as okra, snap beans, and garden peas, low-temperature storage has been used to increase shelf life. This is because most metabolic reactions are slowed down at low temperatures, allowing produce to remain in stable condition for a long time (Kays 1991, Wills et al. 1981).

Genotypes differ in physiological characteristics such as cell turgor, respiration, soluble sugar content, and the levels of amino acids and organic acids (Phan et al. 1973). Jain et al. (1980), working on both short- and medium-duration vegetable-type pigeonpea, showed differences in sugar and starch content. Sugar content varied from 10.7 to 14.8% in short-duration types, and from 7.3 to 12.9% in medium-duration types. What is not known is whether these differences cause variations in shelf life of vegetable pigeonpea. Eheart (1970) showed that the retention of ascorbic acid, acidity, and chlorophyll depended upon the genotype of broccoli. This has not been shown in vegetable pigeonpea.

Reduced ascorbic acid or ascorbic acid is one of the more important nutrients supplied by some fresh fruits and vegetables. It is one of the most sensitive to destruction when the commodity is subjected to adverse handling and storage conditions (Kays 1991) and is commonly used as a measure of deterioration of produce. Loss of ascorbic acid in peas and beans may be retarded by storing these vegetables in the pod. Shelled lima beans lose ascorbic acid at twice the rate of unshelled beans at the same temperature (Heinze 1974).

There is a growing export market for green pigeonpea. Exporters are keen to have high-yielding varieties with acceptable market traits. In addition, they are looking for varieties with long shelf life or conditions that would allow for long shelf life. The overall objective of this study was therefore to determine the storage stability of pigeonpea pods and green peas under different storage conditions. The specific objective was to determine the effect of genotype, storage temperature, duration of storage, and shelling on reduced ascorbic

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acid, Total Soluble Solids (TSS), Total Titratable Acidity (TTA), and moisture content of vegetable pigeonpea.

Materials and Methods

Eight genotypes identified by ICRISAT as suitable for grain or vegetable use were grown at the Kabete Held Station of the University of Nairobi to determine the effect of genotype, storage temperature, shelling, and storage duration on the quality of vegetable pigeonpea in storage. The genotypes were ICPLs 87091, 90029, 93015, 93020, 93027, 93047, 93064, and ICP 7035.

The genotypes were grown using normal cultural practices as described by van der Maesen (1980) on plots measuring 6 x 6 m. Treatments were arranged in a completely randomized block design, replicated four times. Two to three seeds were placed per hole at a spacing of 30 cm and covered with soil. The plots were kept weed-free by manual weeding. At the start of flowering, the crop was sprayed with Rogor L40 (Japan) at 0.7 L ha^{-1} to control pod-sucking bugs, pod fly, and pod-boring larvae. No fertilizer was applied.

Green pods bearing fully developed seeds obtained 25 days and 30 days after flowering were used. A batch of 1 kg was taken from each genotype. Half of this (500 g) was shelled by hand. Shelled and unshelled peas were packaged in perforated polythene bags (micro-evaporator, gauge 150, Kenpoly) and each set was divided into two groups. One group was stored at room temperature (21±3°C) and the second group at 4±1°C (refrigerator) for either 2 or 4 days. A sample of fresh peas (before storage) was used as a control. The treatment combinations were therefore as follows:

1. Fresh peas, before storage (control)
2. Shelled and stored for 2 days at room temperature
3. Unshelled and stored for 2 days at room temperature
4. Shelled and stored for 2 days in the refrigerator
5. Unshelled and stored for 2 days in the refrigerator
6. Shelled and stored for 4 days at room temperature
7. Unshelled and stored for 4 days at room temperature
8. Shelled and stored for 4 days in the refrigerator
9. Unshelled and stored for 4 days in the refrigerator

Moisture content, ascorbic acid, TSS, and TTA of the peas were determined as described below, at the end of the storage period.

Determination of variables

Moisture content. Moisture content was determined only at day 4 of storage, using AOAC methods (AOAC 1984). A sample of peas weighing 100 g was oven dried at 60°C for 24 h, dried further at 105°C for 1 h, and then weighed. The moisture content was calculated as the loss in mass, expressed as a percentage of initial mass.

Total Soluble Solids. TSS (°Brix) was determined by crushing a few peas (about 2 g) using a mortar and pestle. A little juice was squeezed onto the glass of a hand refractometer (Abbe-type, Japan) (AOAC 1984) and measurements recorded.

Reduced ascorbic acid (Vitamin C). Reduced ascorbic acid was determined by the method of Barakat et al. (1955). A sample of peas weighing 2 g was blended with 10 mL of 20% trichloroacetic acid solution to homogeneity. The slurry was titrated with a standard solution of N-bromosuccinimide and the reduced ascorbic acid calculated from the formula:

Reduced ascorbic acid (mg/100g) = V*C*176/178,
where V = volume of N-bromosuccinimide, C = concentration of N-bromosuccinimide.

Total Turntable Acidity. TTA was determined by AOAC (1984) methods. A sample of 2 g of peas was crushed completely to a slurry using a mortar and pestle. In a 300 mL conical flask, 10 mL of carbon dioxide free water was added to the slurry. The mixture was then titrated with a standard solution of 0.1 N NaOH. TTA was calculated as grams/kilogram equivalent of malic acid (the predominant organic acid in pigeonpea) using the formula:
TTA (g/kg) = Amount of 0.1N NaOH * malic acid equivalent

Data analysis

Data were analyzed using Genstat statistical software. Treatment means were separated using LSD procedure at $P \leq 0.05$. Results from peas harvested 25 and 30 days after flowering were similar. Hence, only results from the latter group are presented.

Results

Reduced ascorbic acid (Vitamin C)

Reduced ascorbic acid differed among genotypes at different storage temperatures, whether shelled or unshelled, at all storage durations (Table 1). Room temperature storage of peas led to high losses of reduced ascorbic acid in all genotypes. Losses were lower in refrigerated peas, and lower still when peas were stored unshelled. There was no loss in reduced ascorbic acid in unshelled peas of three genotypes (ICPLs 93020, 93064, 93047) when stored for 2 days. Peas of five genotypes - ICPLs 93020,93015, 93064,93027, and 93047 - whether shelled or unshelled, showed a high decrease in reduced ascorbic acid under room temperature storage. Unshelled peas of ICP 7035 showed the least loss of reduced ascorbic acid upon room temperature storage.

Total Soluble Solids (TSS)

TSS for vegetable pigeonpea differed significantly among genotypes at different storage temperatures whether shelled or unshelled (Table 1). TSS decreased under all storage conditions for all genotypes. Refrigerated peas showed a higher TSS compared to shelf-stored peas. Unshelled refrigerated peas showed the highest TSS, especially upon storage for 4 days. Under room temperature storage, TSS increased in all genotypes upon storage

Table 1. Reduced ascorbic acid content and total soluble solids in different vegetable pigeonpea genotypes under varying storage conditions.

Genotype	Fresh	Shelf storage (21+3°C)				Refrigerated storage (4+1°C)			
		Shelled 2 days	Shelled 4 days	Unshelled 2 days	Unshelled 4 days	Shelled 2 days	Shelled 4 days	Unshelled 2 days	Unshelled 4 days
Reduced ascorbic acid (mg/100 g)									
ICPL 87091	32.9a	22.4d	16.3e	23.2d	16.9e	25.8c	23.5d	28.1b	26.3bc
ICPL 90029	31.6a	19.9d	15.8e	21.7d	17.1e	24.8cd	24.3c	28.6b	28.0b
ICP 7035	35.1a	24.3cd	16.6f	28.0b	20.7e	23.9cd	22.5de	25.8c	25.7c
ICPL 93020	27.0a	16.4d	8.4e	16.9d	9.8e	19.4c	22.5b	25.5a	22.2b
ICPL 93015	30.4a	18.6e	9.2f	21.7d	11.0f	18.6e	20.4de	28.0b	25.8c
ICPL 93064	27.8a	18.7d	8.2f	19.6cd	12.6e	20.9c	20.6cd	26.5ab	25.3b
ICPL 93027	28.0a	20.6d	6.4f	21.4cd	12.5e	20.7d	20.9d	25.5b	23.4bc
ICPL 93047	27.0a	21.7d	8.4f	22.2d	10.8e	24.3bc	22.2d	25.2ab	22.9cd
Mean	30.0	20.3	11.2	21.8	14.0	22.4	22.1	26.7	25.0
SE±	1.24								
Total soluble solids (TSS) (°Brix)									
ICPL 87091	16.0a	12.4d	8.5f	10.3e	12.5d	15.0b	14.1c	16.1a	15.1b
ICPL 90029	16.0a	12.0d	10.5e	10.5e	14.3bc	10.6e	13.6c	13.7c	15.8ab
ICP 7035	16.0a	10.0d	8.0e	9.7d	11.5c	11.1c	14.2b	16.0a	16.0a
ICPL 93020	15.2a	9.8e	11.0d	10.3de	10.7d	12.2c	12.3c	13.2b	13.3b
ICPL 93015	14.5a	10.7d	10.7d	10.0d	10.2d	13.3b	13.2c	13.0c	14.0ab
ICPL 93064	13.8ab	10.0f	10.8de	10.5e	10.7e	11.5d	12.7c	13.4bc	14.3a
ICPL 93027	15.2a	11.3c	10.3d	10.3d	10.7cd	10.7cd	12.7b	13.0b	13.3b
ICPL 93047	14.8a	9.3f	10.3e	10ef	10.5e	11.6c	13.8bc	13.2c	14.3ab
Mean	15.2	10.7	10.0	10.2	11.4	12.0	13.3	14.0	14.5
SE±	3.4								

Significant at $P \leq 0.05$. Means followed by the same letter along a row are not significantly different for 4 compared to 2 days in unshelled peas. However, TSS decreased in ICPLs 87091, 90029,93027 and ICP 7035 during shelf storage.

Total Titratable Acidity (TTA)

TTA for vegetable pigeonpea differed significantly among genotypes at different storage temperatures whether shelled or unshelled (Table 2). There were largely no pronounced differences in TTA between shelf-stored and refrigerated peas. However, mere was a decrease in TTA in ICPLs 87091,93020,93015, and 93047, when unshelled; and in shelled refrigerated ICPL 87091 stored for 4 compared to 2 days. TTA in the other genotypes was not significantly affected by shelling or duration of storage.

Moisture content

Moisture content differed among genotypes at different storage temperatures, whether shelled or unshelled (Table 2). ICPL 87091 did not differ in moisture content under the different treatments compared to the control (fresh peas), indicating that the variety stores well. Several varieties showed poor storage quality; for example ICP 7035, ICPL 93015, and ICPL 93020 (whether shelled or unshelled) lost moisture under shelf storage. However, shelled refrigerated peas generally had similar moisture content as fresh peas, indicating that for most genotypes, the best way to lengthen shelf life is to refrigerate.

Discussion

Fresh produce is stored for future use or to allow transportation over long distances. The quality of the produce is not supposed to change appreciably during storage. Over time in storage, however, reduced ascorbic acid (vitamin C) and sugars get depleted and the functional properties of proteins may be affected (Kays 1991). The eating quality may also change appreciably.

Reduced ascorbic acid is one of the nutrients that is most labile to processing and handling of fresh produce. It is therefore used as an index of destruction of other nutrients (Kays 1991, Wills et al. 1981). Higher ascorbic acid losses occurred following shelf storage (21±3°C) than in the refrigerator (4±1°C) in this study. The losses were higher in shelled than in unshelled peas. Minimum ascorbic acid losses were observed in unshelled refrigerated pods. Shelling allows for higher gaseous exchange in the peas and therefore accelerates oxidative reactions and loss of reduced ascorbic acid (Bender 1994). In this study, the genotypes were shown to differ in their reduced ascorbic acid content, as reported elsewhere (Jain et al. 1980) for other vegetables. This shows that ascorbic acid content is genotypically dependent.

TSS of vegetable pigeonpea decreased in storage. The decrease was more dramatic when the peas were shelled and stored at room temperature. High temperatures accelerate reactions such as breakdown of sugars to release energy (Wills et al. 1981, Kays 1991). Such losses in sugar quantity (and hence lowered TSS) could have occurred more at higher storage temperatures than under refrigeration. Shelling may allow for easy exchange of

Table 2. Total titratable acidity and moisture content in different vegetable pigeonpea genotypes under varying storage conditions.

Genotype	Fresh	Shelf storage (21±3°C)				Refrigerated storage (4±1°C)			
		Shelled 2 days	Shelled 4 days	Unshelled 2 days	Unshelled 4 days	Shelled 2 days	Shelled 4 days	Unshelled 2 days	Unshelled 4 days
Total titratable acidity (TTA) (g/kg)									
ICPL 87091	1.5a	1.2bc	1.2bc	1.2cd	1.2bc	1.4ab	1.1c	1.3b	1.1d
ICPL 90029	1.5a	1.3bc	1.5a	1.2b	1.3b	1.2b	1.2b	1.3b	1.2cd
ICP 7035	1.4a	1.2b	1.2b	1.3ab	1.2b	1.2b	1.2b	1.2b	1.2b
ICPL 93020	1.6a	1.3b	1.3b	1.3b	1.3b	1.3b	1.1c	1.4b	1.1c
ICPL 93015	1.3b	1.2bc	1.2bc	1.4a	1.3b	1.3b	1.2bc	1.4a	1.1c
ICPL 93064	1.4a	1.3ab	1.2b	1.2b	1.2b	1.3ab	1.3ab	1.2b	1.2b
ICPL 93027	1.5a	1.3b	1.1c	1.3b	1.1c	1.3b	1.2bc	1.2bc	1.2bc
ICPL 93047	1.5a	1.2bc	1.3b	1.3b	1.2bc	1.4ab	1.3b	1.3b	1.1c
Mean	1.5	1.3	1.3	1.3	1.2	1.3	1.2	1.3	1.1
SE±	0.1								
Moisture content (%)									
ICPL 87091	75.2a		74.1a		74.5a		76.0a		74.1a
ICPL 90029	76.7a		72.1b		73.0ab		73.1ab		72.2b
ICP 7035	76.6a		70.0c		73.1b		75.3ab		71.7bc
ICPL 93020	77.2a		73.0b		71.0b		74.3ab		73.5ab
ICPL 93015	74.0a		57.5c		68.7b		72.5ab		72.9a
ICPL 93064	75.0a		71.6ab		69.1b		73.7a		74.0a
ICPL 93027	77.2a		75.0ab		71.5b		76.0a		75.2ab
ICPL 93047	77.5a		75.2ab		71.4b		77.5a		76.9a
Mean	74.9		71.1		71.5		73.7		75.0
SE±	3.1								

Significant at P≤ 0.05. Means followed by the same letter along a row are not significantly different gases between the inside of the peas and the outside environment, accelerating processes such as respiration - hence a high breakdown of sugars leading to a decrease in TSS. All genotypes in this study showed increase in TSS after 4 days compared to 2 days of unshelled room temperature storage. However, under refrigeration, only genotypes ICPLs 90029, 93015, and 93047 showed similar responses, indicating that they store poorly. This suggests that the response of TSS in storage is genotypically dependent.

Low temperature storage of shelled garden peas has been shown to lead to a decline in acidity (Heinze 1974). In storage, there is competition between anabolic and catabolic reactions. Probably, the catabolic reactions are faster than the anabolic reactions of the acid in the peas, leading to the decline in acidity. These observations may explain the results of this study where refrigerated storage for 4 days led to a decline in acidity in some genotypes. Shelling before storage accelerated the decline. This could have been due to the easy exchange of oxygen and other gases that speed up various catabolic reactions such as respiration, the main path of breakdown of acids. At high temperatures, oxidative reactions are activated and nutrients such as soluble sugars are broken down to release energy, and hence get depleted faster than the acids, leading to a low sugar:acid ratio (Dennis 1981).

High temperatures in storage increase the rate of moisture loss from stored produce. Moisture loss is fastest in leafy vegetables and small seeds which have a high surface area/ volume ratio (Kays 1991). Moisture loss is also accelerated by high temperatures. Low temperature storage would therefore reduce transpiration and moisture loss in fresh produce (Kays 1991, Wills et al. 1981). In this study, low moisture content under room temperature storage was observed in ICPLs 93015,93020,90029 and ICP 7035 (all shelled), and ICPLs 93047, 93027, 93064,93015, 93020 and ICP 7035 (unshelled).

Conclusions

Storage of vegetable pigeonpea after shelling and at high temperature accelerates quality losses, i.e. decrease in reduced ascorbic acid, TSS, and increase in TTA. Nutrients decreased significantly at room temperature but remained relatively constant under refrigeration. Storage in pods extends shelf life, particularly under low temperature. The results of this study suggest that vegetable pigeonpea keeps well when stored either under low temperature or as pods. This helps to maintain both nutritional and organoleptic quality. The studies further show that response to storage conditions is genotypically dependent. It is, however, important to balance the good keeping quality of unshelled peas against the higher storage costs - shelling considerably reduces bulk and therefore storage costs. No wonder then, most grain vegetables the world over, will be stored shelled.

References

AOAC (Association of Official Analytical Chemists). 1984. Official methods of analysis. 14th ed. Washington, DC, USA: AOAC.

Barakat, M.Z., El-Wahab, M.F.A., and El-Sadr, M.M. 1955. Action of N-bromosuccinimide on ascorbic acid: new titrimetric method for estimation of reduced ascorbic acid. Analytical Chemistry 27:536-540.

Bender, A.E. 1994. Nutritional aspects of frozen foods. Pages 123-129 *in* Frozen food technology (Mallet, C.P., ed). London, UK: Chapman and Hall.

Dennis, C. 1981. The effect of storage conditions on the quality of vegetables and salad crops. Pages 329-339 *in* Quality of stored and processed vegetables and fruits (Goodenough, P.W. and Atkins, R.K., eds). London, UK: Academic Press.

Eheart, M.S. 1970. Effect of storage and other variables on composition of frozen broccoli. Food Technology 24:1009-1011.

Heinze, P.H. 1974. The influence of storage, transportation, and marketing conditions on composition and nutritional values of fruits and vegetables (White, P.L.. and Selvey, R.D.N., eds). New York, USA: Futura Publishing.

Hurst, P.L., Borst, W.M., and Hannan, P.J. 1993. Effect of harvest date on the shelf life of asparagus. New Zealand Journal of Crop and Horticultural Science 21:229-233.

Jain, K.C., Sharma, D., Gupta, S.C., Reddy, L.J., and Singh, U. 1980. Breeding for vegetable type pigeonpea. *In:* Vol 2, Proceedings of the International Workshop on Pigeonpea, 15-19 Dec 1980, Hyderabad, India. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Kays, J.S. 1991. Postharvest physiology of perishable plant products. New York, USA: Van Nostrand Reinhold.

Maesen, van der L.G. 1980. *Cajanus* DC and *Atylosia* W & A (Leguminosae). Agricultural University Wageningen Papers 85-4 (1979). Wageningen, the Netherlands: Agricultural University. 255 pp.

Phan, C.T., Hsu, H., and Sarkar, S.K. 1973. Physical and chemical changes occurring in the carrot root during storage. Canadian Journal of Plant Science 53:635.

Wilis, R.B.H., Lee, T.H., Graham, D., McGlasson, W.B., and Hall, E.G. 1981. Water loss and humidity. Pages 52-59 *in* Postharvest: an introduction to the physiology and handling of fruits and vegetables, 3rd ed. Westport, CT, USA: AVI.

Evaluation of Dry Mature Pigeonpea Seeds for Processing and Eating Quality

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Introduction

Several pigeonpea cultivars have been developed through collaborative efforts by the Kenya Agricultural Research Institute, the University of Nairobi, and ICRISAT. While these cultivars possess a number of traits acceptable to farmers and the market, they must be assessed for all aspects of consumer needs.

Cooking trials were carried out in the Department of Food Technology and Nutrition of the University of Nairobi to compare the acceptability, cookability, and nutrient content of four pigeonpea varieties (ICEAP 00040, Kat 60/8, ICP 6927, ICEAP 00540), with a view to identifying an optimal cultivar for end-user needs.

Dry mature seeds of the four cultivars were evaluated for processing and eating quality. Processing quality was evaluated in terms of cookability and soaking properties; and eating quality in terms of nutritional value, sensory attributes, and consumer acceptability. Soaking times and the effect of soaking on cooking time were compared. Crude protein and amino acids were determined in both raw and cooked products in order to quantify nutritional changes caused by the cooking process. The cooked product was evaluated for sensory quality and acceptability by an untrained panel.

Materials and Methods

The pigeonpea varieties used in this evaluation included improved African lines (ICEAP 00040, ICEAP 00540), an improved Kenyan line (Kat 60/8), and an exotic Caribbean line (ICP 6927). Seeds were obtained from the Dept of Crop Science at the University of Nairobi, packed in polyethylene bags. These had been stored at temperatures of 20-25°C. Raw seeds were sorted and cleaned, then soaked for 17 hours, and finally boiled for 35 minutes. The experimental design used is shown in Fig 1.

The proximate composition of raw, soaked (17 h at 25°C), and cooked pigeonpea was analyzed using standard AOAC methods (AOAC 1984). Prior to analysis, raw samples (dry mature seeds) were sun-dried in an air oven at 70^0 C for 12 h, and then ground using a hammermill.

Amino acids in the raw and cooked samples were detected qualitatively using Thin Layer Chromatography.

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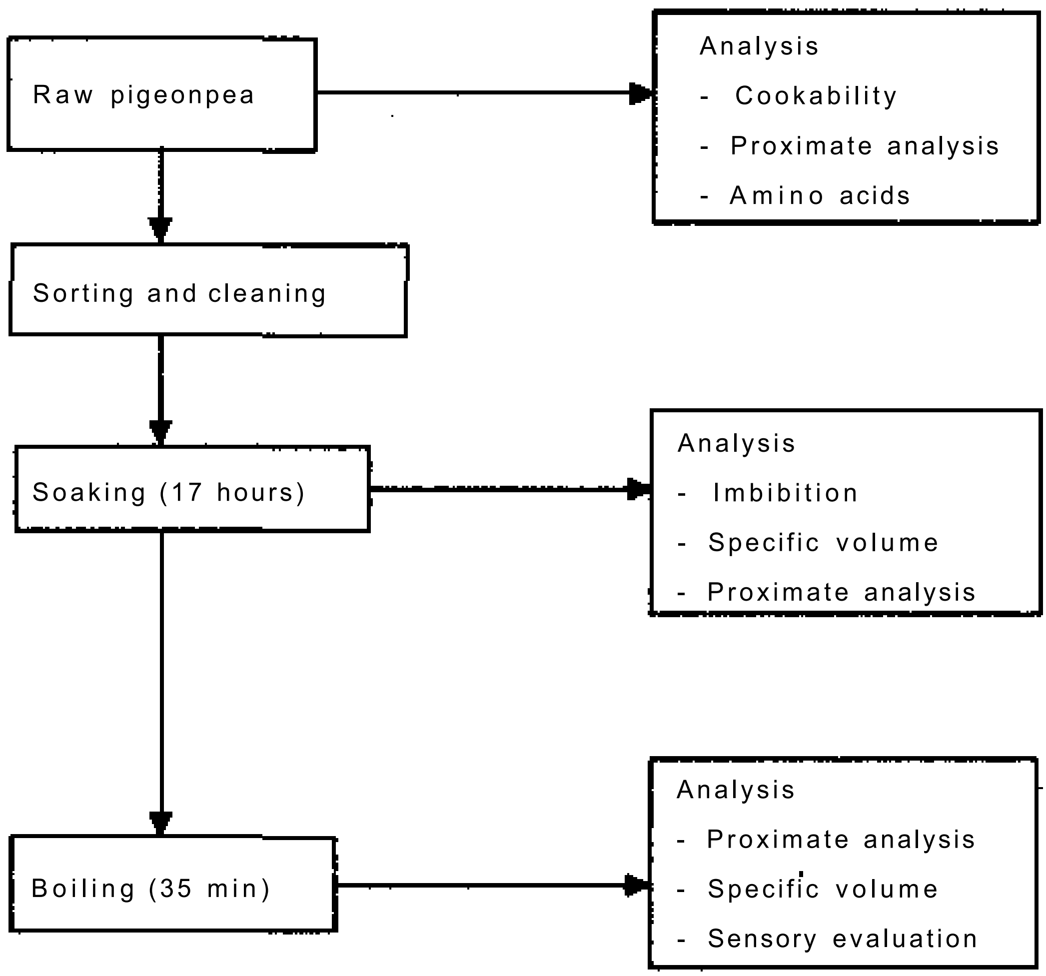
Figure 1. Experimental design.



The cookability of dry mature pigeonpea and pre-soaked (17 h) pigeonpea was determined subjectively. This was done by boiling a 50-g sample of pigeonpea that had been sorted and cleaned. Cookability was determined by:

- Pressing the seed between the thumb and index finger. The pigeonpeas were considered cooked at the point they mash.
- Cutting the seeds using the incisors and grinding using the molars. The mouthfeel and ease of chewing were used to determine whether the seeds were cooked.

Samples for sensory evaluation were prepared as follows. Pigeonpeas were boiled until cooked. The cooking end point was determined subjectively as described above. The boiled samples were then fried in 20 g of margarine for 2 min. The cooked samples were analyzed for color, taste, texture, and overall acceptance. A 7-point hedonic scale was used for scoring: 7 = Like very much, 6 = Like, 5 = Like slightly, 4 = Neither like nor dislike, 3 = Dislike slightly, 2 = Dislike, 1 = Dislike very much.

Soaking was evaluated at three temperatures - 30, 40, and 60° C - which were maintained using thermostatically controlled water baths. Weighed samples were placed in

600 mL glass beakers containing water. The water was made up to the 500 mL mark by addition of water at the same temperature. The soaking process was studied by obtaining the drained weight and specific volume (cm^3/100 g dry solids) every hour.

The drained weight was obtained by draining the water from the pigeonpea samples every hour. These were placed on standard 1000 µm sieves and drained for 2 min. Seeds were then placed into the solution and the volume made up to 500 mL using tap water at the fixed temperature.

The specific volume (cm^3/100 g dry solids) was obtained by the displacement method, using a 1000 mL volumetric cylinder filled with water. The change in volume was recorded. Specific volume was measured every hour.

Results and Discussion

Soaking reduced cooking time by as much as 70%. The rate of water uptake increased with the temperature of the soaking water. With crude protein measuring above 20%, all four pigeonpea varieties are good sources of protein. Both soaking and cooking reduced the crude protein. Further, cooking destroyed some of the amino acids, thus reducing the biological value of the protein.

It is important to note that all the attributes studied were clearly cultivar-specific and that the panelists voted ICEAP 00040 as the most acceptable cultivar using taste only as the most important sensory attribute in their evaluation.

Proximate composition

In all cultivars, dry weight more than doubled due to water absorption, leading to a significant increase in drained weight on cooking. ICP 6927 had the maximum imbibition on soaking for 17 h at room temperature. Processing resulted in a loss in crude protein, ash, and soluble carbohydrates. Loss in crude protein ranged from 1.2% in ICP 6927 to 5.4% in ICEAP 00540 (Table 1). On average, 3.8% of the crude protein was lost on processing, 2.5% was lost during the soaking stage, and 1.3% was lost on cooking. The loss in crude protein may be due to leaching of nitrogen-containing substances and Maillard reactions on cooking. The increase in fibre and crude protein content is mainly due to a decrease in protein, ash, and soluble carbohydrates, which increases the proportion of crude fibre and fat in the dry matter content.

Amino acid composition

Methionine, phenylalanine, and isoleucine amino acids were not detected (Tables 2 and 3). ICEAP 00040 was the most deficient in the essential amino acids, being deficient in lysine and leucine in addition to the above - it contains only 3 out of the 9 amino acids tested. On processing, a loss in leucine was observed in all cultivars. Other losses detected seemed to be cultivar-specific: lysine in ICEAP 00540, tryptophan in ICEAP 00040, tyrosine in Kat 60/8 and ICP 6927.

Table 1. Proximate composition of pigeonpea seeds, showing the effect of composition on processing.

Proximate	ICEAP 00540			ICEAP 00040			Kat 60/8			ICP 6927		
composition	Raw	Soaked	Cooked	Raw	Soaked	Cooked	Raw	Soaked	Cooked	Raw	Soaked	Cooked
% moisture	11.5	159.73	206.5	10.01	163.03	194.15	12.78	156.87	194.44	14.61	179.25	212.52
% protein	23.18	22.71	22.62	22.39	21.61	21.52	23.94	23.66	22.84	23.07	22.98	22.79
% crude fat	1.41	2.16	2.23	1.80	2.66	2.87	1.31	2.53	3.11	1.94	2.67	3.13
% fiber	9.52	12.11	12.45	7.71	10.06	10.57	8.60	8.98	9.95	10.98	11.4	13.82
% ash	4.2	3.56	3.53	4.38	3.87	3.33	10.15	4.66	2.94	4.70	3.93	3.14
% CHO	61.62	59.46	59.17	63.01	61.8	61.61	56.00	60.1	61.16	59.32	59.02	57.12

Table 2. Amino acid composition of raw, dry, mature pigeonpea seeds.

Cultivar	Valine	Methionine	Tyrosine	Lysine	Phenyl-alanine	Leucine	Tryptophan	Isoleucine	Threonine
ICEAP 00540	✔	–	✔	✔	–	✔	✔	–	✔
ICEAP 00040	✔	–	✔	–	–	–	✔	–	✔
Kat 60/8	✔	–	✔	✔	–	✔	✔	–	✔
ICP 6927	✔	–	✔	✔	–	✔	✔	–	✔

Table 3. Amino acid composition of processed pigeonpea cultivars.

Cultivar	Valine	Methionine	Tyrosine	Lysine	Phenyl-alanine	Leucine	Tryptophan	Isoleucine	Threonine
ICEAP 00540	✔	–	✔	–	–	–	✔	–	✔
ICEAP 00040	✔	–	✔	–	–	–	–	–	✔
Kat 60/8	✔	–	–	✔	–	–	✔	–	✔
ICP 6927	✔	–	–	✔	–	–	✔	–	✔

The soaking process

Pigeonpea is stored as dry mature seed. This makes soaking an essential part of processing. Soaking has many advantages including:

- Improving digestibility of the product by blocking the active sites of protease inhibitors and leaching out trypsin factors, thus inhibiting the activity of antinutrient factors (Erpenyong and Brochers 1986)
- A softening effect which reduces cooking time by removing trapped gases from interstitial tissues of dry legumes (Sefa-Dedeh and Stanley 1984, Kon 1979)
- Aiding in the cleaning operation
- Increasing moisture content and hence water activity, which is necessary for germination and fermentation processes.

Water pickup curves were obtained to facilitate the study of the soaking process. The absorption curves were obtained in terms of drained weight and specific volume[1]. The extent and rate of water imbibition depended on the cultivar and the temperature of the soak water. The time needed to absorb the maximum water is shown in Table 4 for the cultivars at different soak water temperatures.

An increase in temperature led to a reduction in soaking time. An increase in soak water temperature from 30°C to 40°C and 60°C reduced soaking time to maximum imbibition by 30% and 70%, respectively. This reduction is explained by the removal of trapped gases (nitrogen, oxygen, carbon dioxide) from interstitial tissues of the seeds. This effectively reduces resistance to mass transfer. However, high-temperature soaking also causes losses in nutrient content. A study on the effect of soaking temperature on cooking and nutritional quality of beans (Kon 1979) found that nutritional losses were minimal at a soaking temperature of 40°C, but increased by up to four-fold when the temperature was raised to 60°C and above. Nutrient losses were not significant between 25-40°C but were significant at 60°C.

The maximum imbibition corresponds to the maximum drained weight of the sample. The maximum imbibition measured on dry weight basis seems to vary with the cultivar used. ICEAP 00040 gave the highest drained weight when soaked at 40°C and 60°C.

Specific volume is important especially where the product is to be canned. Specific volume increases with an increase in drained weight, and increases by as much as 100% in the soaking process. This parameter is important in determining the fill weight of the can.

Cookability

Cookability of the raw seeds was defined as the time taken for clean dry pigeonpeas to cook without prior soaking. Without soaking, about 2 h are required for pigeonpea to cook: ranging from 2 h 22 min for ICEAP 00040 to 1 h 50 min for ICP 6927. When soaked for 17 h, the pigeonpeas were cooked in 35 min. Soaking thus reduced the cooking time by 80%, implying large savings in energy consumption. This not only saves cost, but also improves

1. Detailed data not shown due to space limitations. Contact authors for mote information.

Table 4. Maximum imbibition (g of water per 100 g dry seeds) and the time at which this is obtained, for various cultivars at different soaking water temperatures.

Cultivar	30°C		40°C		60°C	
	% dwb	Time (hrs)	% dwb	Time (hrs)	% dwb	Time (hrs)
ICEAP 00540	158.1	14	142.7	9.41	158.1	3.83
ICEAP 00040	-	-	217	7.18	217	4.25
Kat 60/8	134.6	12.26	159.4	11.18	153.7	3.6
ICP 6927	159	11.2	168.2	8.0	165.9	3.5

% **dwb** = grams of water per 100 g of solids

Table 5. Sensory scores for cooked pigeonpea seeds.

	ICEAP 00540	ICEAP 00040	Kat 60/8	ICP 6927
Color	4.8	5.07	5.87	5.33
Texture	5.33	5.4	5.53	4.86
Taste	5.87	5.93	5.4	4.8
Overall acceptance	5.0	5.53	5.6	4.73

Scores on **a** 1-7 scale where 1 = Dislike very much, 4 = Neither like nor dislike, 7 = like very much

quality due to reduced antinutrient content. The soaking process reduces cooking time in two ways: softening of the tissues, which renders them easier to cook; and reducing interstitial gases and thus increasing the heat transfer coefficient of the pigeonpeas.

Sensory evaluation

Generally, all the attributes tested scored above 4 on a 1-7 scale, i.e. Neither like nor dislike. The results indicate that taste was the most important selection criterion for the consumer. The taste of ICEAP 00040 was the most preferred, while ICP 6927 scored the highest on overall acceptance (Table 5).

Conclusions

A wide range of pigeonpea cultivars is available. While many may possess valuable agronomic and other characteristics, they must be assessed for consumer acceptance. Consumers in this study selected ICEAP 00040 mainly using taste criteria. Since consumer preference is influenced mostly by eating quality, it is important for breeders to work closely with food technologists, who understand the nutritional needs and sensory expectations of the consumer. This will help identify cultivars that combine good yield, agronomic and similar characteristics with nutritional quality and consumer preferences.

References

AOAC (Association of Official Analytical Chemists). 1984. Official methods of analysis. Arlington, Virginia 22209, USA: AOAC.

Erpenyong, T.E. and Brochers, R.L. 1986. Effect of cooking on the chemical composition of winged beans. Journal of Food Science 45:1559-1560 and 1565.

Kon, S. 1979. Effect of soaking temperature on cooking and nutritional quality of beans. Journal of Food Science 1979:1329-1334.

Sefa-Dedeh, S. and Stanley, A.W. 1979. The relationship of microstructure of cowpeas to water absorption and dehulling properties. Journal of Cereal Chemistry 56 (4):379-385.

Integrated Management of Postharvest Pests of Pigeonpea: Status and Potential

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Introduction

Pigeonpea has great potential as a food security and income-generating crop, especially in northern Uganda. An estimated 22,000 tons are produced from 63,000 ha in these relatively dry areas, almost entirely by small-scale subsistence farmers (Nalyango and Emeetai-Areke 1987). The predominant varieties are medium- and long-duration cultivars that often take more than 6 and 9 months respectively to mature and thereafter can be ratooned. In the recent past, however, elite short- and medium-duration varieties have been introduced from ICRISAT. Of these, Kat 60/8, ICPL 87091, ICP 6927, and ICEAP 00068 have been released.

Pigeonpea production and subsequent post-production systems face several constraints including poor seed quality, lack of genetic improvement, poor agronomic practices, diseases, field and storage insect pests, low utilization, and poor processing techniques (Silim-Nahdy et al. 1991). Among the insect pests, there are species that feed on flowers, pods, and seeds. Pod and seed feeders cause high damage levels since both field and storage infestation occur. In Uganda, the adzuki bean weevil, *Callosobruchus chinensis* L. that begins its infestation in the field and continues during storage, is considered the most serious pest of pigeonpea.

In field infestation, adult female bruchids lay eggs on mature pigeonpea pods and the larvae bore into seeds upon hatching. Pods that are dehisced or damaged by the American bollworm *Helicoverpa armigera* are more susceptible to *C. chinensis* infestation and this leads to rapid population build-up. Non-dehisced dry pods are not easily infested. The level of field infestation is also determined by pod hair density. Fewer eggs are laid on pods that are more hairy, and subsequent infestation build-up is lower (Silim-Nahdy 1995).

Pre-harvest infestation by bruchids may often cause only limited damage, but has serious implications on storage duration. This is because the insects multiply very rapidly within a short time once transferred to storage, and this results in high damage levels. Under poor storage sanitary conditions, cross infestation also occurs, with larvae moving onto uninfested pods. Heavy losses occur within 4-8 weeks of storage (Taylor 1981, Dobie 1981).

To quantify the economic importance of bruchids on pigeonpea, it is imperative that a reliable loss assessment technique is established to determine the points, levels, and time series of losses. This will help not only in taking rational decisions on pest management

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options but also in determining what level of intervention is needed, and how to allocate limited resources to the development of pest control tools.

Management of Bruchids on Pigeonpea

Pigeonpea storage over long periods is limited due to bruchid infestation that results in heavy losses at small-scale subsistence farming levels. To avoid excessive losses, most farmers are forced to sell off surplus grain immediately after harvest, when prices are lowest (Silim-Nahdy 1995). Although it is generally known that infestation starts in the field, there is little information on field management methods, apart from the recommendations of early harvest and intercropping to reduce subsequent storage infestation (van Huis 1991). Silim-Nahdy (1995) observed reduced field bruchid load in storage when Cypermethrin 5% EC was applied routinely to control pod borers and suckers in the field. Aloci (2000) screened several botanicals including synthetic insecticides to control field infestation and noted marked reductions of bruchid loads in some of the treatments (Table 1).

Although various pest management methods are available, they are only targeted at reducing and/or controlling losses due to bruchids during storage. We report here on work that includes field and storage control.

Cultural/traditional control methods

A few cultural practices have been observed to reduce bruchid damage in storage. These include timely harvest (Paddock and Reinhard 1919), crop hygiene (De Lima 1973), and maize/bean intercropping. Specific methods for pigeonpea include pod storage and splitting of seeds prior to storage (Silim-Nahdy 1995).

Physical control methods

Physical control methods available include those technologies that can cause 100% mortality to all stages of the pest. These include solarization (solar heating) and hermetic storage (Kitch et al. 1992, Agona and Silim-Nahdy 1998). In Uganda, Silim-Nahdy (1995) observed that the traditional sealed storage structure *(tua)* was a very effective method of eliminating *C. chinensis* populations on pigeonpea. Other useful physical methods include inert dusts such as bentonite, lime, clays, and ash (Maceljski et al. 1970, Wegmann 1983).

Pest management using botanicals

The method involves the use plant materials (leaves, fruit, bark, fruit kernels, and oil extracts) that are applied as admixtures in the correct proportions to control bruchid infestation. The efficacy of botanicals, however, varies depending on which part of the plant is used, pest species, dosage rates, and storage duration. Silim-Nahdy (1995) screened several plant materials and observed that Tephrosia and fire-cured tobacco were the most effective (Table 2). Results of an on-farm trial conducted in Lira, Uganda strongly suggest the superiority of Tephrosia over previously studied (and validated) treatments (Fig. 1).

Table 1. Adult emergence of *Callosobruchus chinensis* and seed damage on pigeonpea after 1 and 2 months of storage, 1998a, 1998b, and 1999a seasons.

	1998a			1998b			1999a		
Treatment	Onset	1 month	2 months	Onset	1month	2 months	Onset	1 month	2 months
No. of adults emerging from 200 g of seed									
Fermented MSE	0.25 d	0.25 d	0.50 de	2.00 ab	3.75 c	11.00 e	1.18 a	5.00 cd	10.50 cd
Fermented Teph	0.25 d	0.75 cd	1.25 d	1.75 ab	2.50 de	8.75 f	1.06 a	4.31 cd	9.80 cd
Fresh MSE	1.50 c	1.25 bc	2.25 c	2.50 ab	5.25 b	18.50 c	1.27 a	6.50 c	13.50 c
Fresh Teph	2.50 b	1.75 b	2.75 bc	2.00 ab	3.50 cd	12.50 de	1.18 a	6.00 c	12.30 c
Fresh tobacco	0.25 d	0.25 d	0.25 e	1.25 b	2.50 de	7.75 f	0.97 a	3.00 de	9.80 cd
Filtered ash	3.00 b	3.00 a	3.50 ab	3.00 a	9.25 a	48.00 b	1.35 a	15.80 b	24.50 b
Tobacco + MSE	1.50 c	0.50 cd	0.75 ce	2.00 ab	3.25 cd	13.30 d	1.31 a	6.00 c	13.00 c
Cypermethrin	0.50 d	0.25 d	0.25 e	0.75 b	2.25 e	3.25 g	1.06 a	2.00 e	7.50 d
Untreated control	4.00 a	3.00 a	4.25 a	2.75 a	9.25 a	59.50 a	1.47 a	21.00 a	31.30 a
CV (%)	39.26	54.97	34.01	41.67	15.92	7.14	30.99	22.91	17.36
LSD	0.96	0.98	0.87	1.22	1.07	2.11	0.54	2.60	3.70
Seed damage (%)									
Fermented MSE	0.48 e	0.59 c	0.97 e	0.70 d	1.96 c	6.04 d	0.48 bc	1.78 b	4.07 b
Fermented Teph	0.47 e	0.59 c	0.89 f	0.46 f	1.84 cd	5.20 e	0.48 bc	1.66 b	3.64 bc
Fresh MSE	0.75 d	0.66 c	1.20 d	0.92 c	2.14 b	7.36 c	0.59 abc	1.97 b	4.66 b
Fresh Teph	0.88 c	1.00 c	1.43 b	0.58 e	1.86 c	7.37 c	0.50 bc	1.87 b	3.87 b
Fresh tobacco	0.35 f	0.55 c	0.80 g	0.39 g	1.83 d	4.04 f	0.43 c	1.21 cd	2.82 d
Filtered ash	0.92 b	1.18 a	1.46 b	1.18 a	2.59 a	10.80 a	0.80 a	2.61 a	6.81 a
Tobacco + MSE	0.78 d	0.89 b	1.37 c	0.49 f	1.84 cd	5.31 e	0.51 bc	1.50 c	3.19 c
Cypermethrin	0.43 e	0.57 c	0.48 h	0.33 h	1.60 e	1.93 g	0.50 bc	0.96 d	1.99 d
Untreated control	1.11 a	1.22 a	1.57 a	1.00 b	2.60 a	9.83 b	0.76 ab	2.84 a	7.32 a
CV (%)	4.80	9.46	3.70	5.14	4.11	6.93	34.65	11.98	12.79
LSD	0.05	0.11	0.06	0.05	0.12	0.63	0.28	0.32	0.79

Means in the same column followed by similar letters are not significantly different (P>0.05)

MSE = Melia seed extract, Teph = Tephrosia

Source: Aloci 2000

Table 2. Efficacy of different plant leaves on emergence and mortality of *C. chinensis* on pigeonpea stored for 2 months.

Treatment	Mean no. of emergent adults	Adult mortality (%)
Burley cured tobacco	20.6 e	87.3 ab
Flue cured tobacco	58.2 d	62.6 cd
Fire cured tobacco	4.6 e	98.6 a
Lantana camara	114.6 c	44.2 d
Water hyacinth	99.2 c	83.5 abc
Tephrosia	4.0 e	100.0 a
Castor oil	113.6c	74.1 bc
Mexican marigold	8.8 e	91.1 ab
Lemon grass	159.4 b	81.7 abc
Untreated control	251.0 a	42.0 d
LSD	22.1	24.1

Means followed by the same letters in each column are not significantly different (P<0.05)
Source: Silim-Nahdy 1995

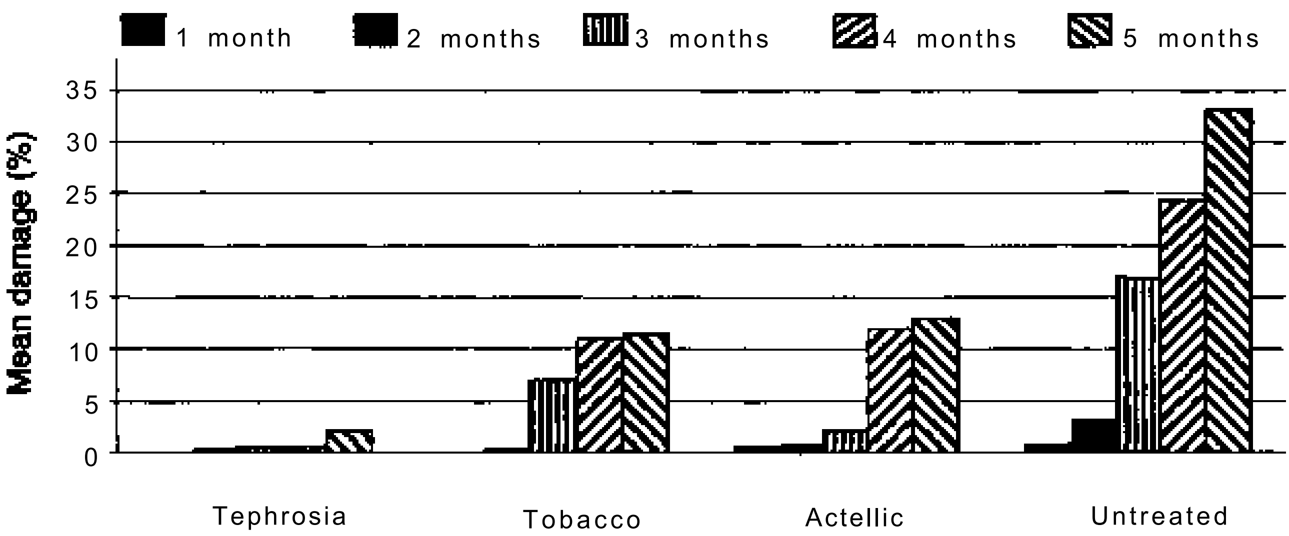

Figure 1. On-farm bruchid damage under different treatments and storage durations, Lira district, 1999 (Agona and Silim-Nahdy 1999).

Coating pigeonpea seeds with oil is also known to offer good protection against *C. chinensis* infestation (Khaire et al. 1992, Silim-Nahdy 1995). Regardless of the source of vegetable oil, crude oil extracts offer better protection against bruchids than purified oils (Schoonhoven 1978).

Chemical control

Farmers consider synthetic insecticides to be the most effective means of bruchid control. When applied correctly and provided strict storage hygiene is followed thereafter, chemical control can ensure total mortality of bruchids and allow long-term storage. Fumigation of pigeonpea with phosphine gas, for instance, is effective against all stages of *C. chinensis.* Laboratory experiments by Agona (1999) showed that Quickphos, Phostoxin, Synfume, and Fumaphos all gave 100% control (nil damaged pods, zero emerging adults), compared to 15% mean damage and large numbers of emerging adults in untreated pigeonpea. Insecticide dust mixtures commonly used to control bruchid damage include Malathion 2% a.i. and Actellic 1% a.i. (Pirimiphos methyl) (Silim-Nahdy et al. 1991). However, the effectiveness of the dust admixtures are variable, depending on shelf life, storage conditions, dosage rates, and the storage environment in which the pesticide is applied.

Field application of Cypermethrin 5% to control pod damage by *H. armigera* has been observed to be effective in reducing C. *chinensis* infestation of stored pigeonpea (Silim-Nahdy 1995, Aloci 2000). Control of *H. armigera* eliminates potential egg laying sites; application of insecticide kills bruchid eggs and 1st larval instars on pigeonpea pods (Silim-Nahdy 1995). There is a strong positive relationship between pod damage and bruchid infestation in storage, especially when no control measures are applied (Aloci 2000). This suggests that pod/seed damage by borers encourages bruchid infestation in the field that continues during storage.

Plant resistance to bruchids

To reach high population densities on pigeonpea seeds, bruchids must find suitable oviposition substrates (including pods and seeds) that encourage egg laying, larval/pupal development, and adult emergence. Silim-Nahdy (1995) observed that fewer eggs are laid on pigeonpea varieties with pods that have high hair densities and are non-dehiscent, and on seeds that are dented/shrivelled - but some of these characteristics, especially dented seeds, reduce market value of the produce.

Adoption of Bruchid Management Technologies

The adoption of recommended bruchid management options depends on effectiveness, availability, cost, and user friendliness. In Uganda efforts have been made to popularize the application of Tephrosia and tobacco leaf powder as admixtures. In areas where these botanicals are not easily available, farmers have been supplied with seeds for multiplication. Farmers are also encouraged to grow Tephrosia around fields to control damage by moles.

Among the physical control methods, solarization is popular with farmers, but it is recommended for grain - not seed - treatment. The traditional *tua,* although very effective, has lost popularity with the easy availability of gunny bags or polypropylene sacks that are portable and can store large volumes.

Adoption of bruchid management methods is contingent upon farmers having enough surplus produce to be stored for long periods. But better storage management will help farmers obtain better prices, and thus provide incentives for further improvements in pigeonpea productivity. Currently, the National Post-Harvest Research Programme, NARO, in collaboration with ICRISAT, has embarked on pigeonpea seed multiplication, To encourage adoption of improved varieties and better pest control methods, pigeonpea, Tephrosia, and/or tobacco seeds are given as a package to interested farmers for multiplication and use.

Conclusions

Bruchids cause high losses on stored pigeonpea, affecting food security and income among smallholder farmers. Proven bruchid management technologies - Tephrosia, tobacco, and solarization - must be disseminated to farmers more effectively. In order to reduce bruchid load into storage, research must focus on field management of pod borers and bruchids.

Acknowledgments

The authors express their gratitude to the National Agricultural Research Organisation (NARO), ICRISAT, and Makerere University for their continued support for pigeonpea research in Uganda.

References

Agona, J.A. 1999. Efficacy evaluation of Fumaphos fumigant against *Sitophilus zeamais, Acanthoscelides obtectus* and *Callosobruchus chinensis.* Technical Report. Entebbe, Uganda: National Agricultural Chemical Control Board, Ministry of Agriculture, Animal Industry and Fisheries. 14 pp.

Agona, J.A. and Silim-Nahdy, M. 1998. The effect of exposure period of beans (*Phaseolus vulgaris)* in a solar dryer on seed viability, cooking time and injuriousness of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). African Crop Science Journal 6(4):417-421.

Agona, J. A. and Silim-Nahdy, M. 1999. On-farm pest management trial in Lira district. Pages 5-14 *in* Technical Report for Project ''Optimising Phytosanitary Operations through Integrated Storage Pest Management and Training in Uganda : STABEX 93 ISPM, 3rd Quarter Report, Jan-Mar 1999.

Aloci, S.K. 2000. Some aspects of cultural practices and use of botanicals in field management of pigeonpea bruchids, *Callosobruchus* spp and other flower and pod pests of pigeonpea. MSc thesis, Makerere University.

De Lima, C.P.F. 1973. A technical report on 22 grain storage projects at subsistence farmer level in Kenya. Project/Research Report 21. Nairobi, Kenya: Department of Agriculture. 23 pp.

Dobie, P. 1981. The use of resistant varieties of cowpea (*Vigna unguiculata*) to reduce losses due to post-harvest attack by *Callosobruchus maculatus.* Series Entomologica 19:185-192.

Khaire, V.M., Kachare, B.V., and Mte, U.N. 1992. Efficacy of different vegetable oils as grain protectants against pulse beetle, *Callosobruchus chinensis* L. in increasing storability of pigeonpea. Journal of Stored Products Research 28:153-156.

Kitch, L.W., Ntoukam, G., Shade, R.E., Wolfsen, J.L., and Murdock, L.L. 1992. A solar heater for disinfesting stored cowpea on subsistence farms. Journal of Stored Products Research 28:261-267.

Maceljski, M., Danon, M. and Koranic, Z. 1970. Comparative research on sensitivity of different stored product beetles on inert dust under various conditions. Pages 439-440 *in* Proceedings of 7th International Congress on Plant Protection, Paris, France.

Nalyango, P.N. and Emeetai-Areke, T.E. 1987. Groundnut and pigeonpea production and improvement in Uganda. Pages 71-80 *in* Summary Proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes, ILCA, Addis Ababa, Ethiopia, 8-10 Dec 1986. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Paddock, F.B. and Reinhard, H.J. 1919. The cowpea weevil. Texas Agricultural Experimental Station Bulletin no. 259.95 pp.

Schoonhoven, A.V. 1978. Use of vegetable oils to protect stored beans from bruchid infestations. Journal of Economic Entomology 71:254-256.

Silim-Nahdy,M. 1995. Biotic and abiotic factors influencing the biology and distribution of common storage pests in pigeonpea. PhD Thesis, University of Reading, UK.

Silim-Nahdy, M., Odogola, W.R., and Amenet, J. 1991. Technical report on post-harvest food losses prevention in Uganda, Project PFL/uGA/001. Kampala, Uganda: FAO and Ministry of Agriculture.

Taylor, T.A. 1981. Distribution, ecology and importance of bruchids attacking grain legumes in Africa. Series Entomologica 19:1999-203.

Wegmann, E. 1983. Holzaschen als wirksames mittel zur Bekampfung von *Callosobruchus maculatus* (F.) in traditonellen bohenlagern West Africa. Gesunde Pfl. 35: 229-234.

Discussions - Postharvest Issues

Storage pests

Storage pests cause considerable losses in both quantity and quality. If pigeonpea is to be commercialized, it is essential to promote better storage practices. Most smallholder farmers do not realize that storage pests are carried over from the field into storage. This is partly because field infestation (egg laying) may cause no visible damage or symptoms immediately; damage begins only after the eggs have hatched. Field pest management as a way to reduce storage losses must form an important part of dissemination efforts.

Technologies are available for control of storage pests. Field and storage pests can often be controlled with the same chemicals, e.g. cypermethrin acts against both *Helicoverpa* and bruchids. Solarization is also effective, but affects germination. Therefore it should be promoted for the protection of stored gain, but not for seed. Field spraying after pod filling is effective, but may be costly. Research should aim to develop more cost-effective packages.

Quality

Market requirements are for large, sweet, green peas. In storage, green peas turn yellow, then creamish. We need to develop quality standards for grading of produce. Nutritional losses can be important, particularly when targeting the health-conscious export market. Additional studies may be needed to minimize losses in moisture and nutrients (e.g. vitamin C and others) in stored peas.

Marketing and Enterprise Development

Sub-Sector Analysis as a Tool for Improving Commercialization and Market Access for Pigeonpea Producers

H A Freeman and R B Jones[1]

Introduction

In many African countries, reform of domestic agricultural markets was expected, among other things, to lead to the development of a more efficient agricultural marketing and distribution system led by the private sector. The resulting gains in marketing efficiency were expected to increase incentives for smallholder farmers to adopt improved technologies that could increase productivity and farm incomes. In reality, however, the benefits from liberalization are proving to be elusive for many smallholder farmers in sub-Saharan Africa. The evidence over the last decade suggests, at best, sluggish supply response to emerging opportunities for commercialization and trade. Private sector participation in agricultural marketing and trade tends to be confined to activities where the cost of entry is low and returns to investments are relatively small. As a result, private investment in trading infrastructure and equipment has not increased significantly following market liberalization.

To take advantage of the opportunities offered by liberalization of agricultural markets, smallholder farmers and market intermediaries need to exploit the dynamic growth effects of the forces of economic change. This implies improved access to efficient markets, post-harvest and distribution systems, effective market information, and improved technologies that will enable smallholder farmers to be competitive both in price and quality in domestic, regional, and international markets. The central challenge facing researchers and development practitioners is therefore to build the competitive advantage of smallholder farmers so that they can produce marketable surpluses over their subsistence needs and engage in market activities that could lead to sustainable creation of wealth in rural areas.

Sub-Sector Analysis: the Analytical Tool

Sub-sector analysis, known in the literature as commodity systems analysis, has been an important analytical tool for developing and assisting the growth of micro- and small-scale enterprises in developing countries (Haggblade and Gamser 1991). Agricultural economists have extensively used this tool to evaluate the market potential of agricultural commodities or other agro-food products. In recent years several development organizations have used sub-sector analysis to evaluate the dynamics of micro- and small-scale enterprises and assess the prospects for interventions that will support the development and growth of businesses in both the agricultural and non-agricultural sectors.

1. International Crops Research Institute for the Semi-Arid Tropics, PO Box 39063, Nairobi, Kenya

It will be useful at this point to define some key concepts that are used in the paper. A sub-sector is a network of firms that supply raw materials, transform them into finished products, and distribute mem through supply channels to final consumers. An agricultural sub-sector might include economic activities from other sub-sectors. In any given sub-sector there are participants who engage in one or more activities (functions) that transform a raw material into a marketed product. A market channel is a vertical production and distribution chain that links participants who perform similar functions using similar technologies. A sub-sector normally consists of a number of different channels that compete for market share. Sub-sector analysis describes a set of concepts and tools that are used to assess the feasibility of interventions within an economic system. An important concept is the sub-sector map. It is used to summarize the structure and dynamics of a sub-sector, identifying key participants, their functions, and the channels that describe the flow of products among the different participants.

Sub-Sector Analysis Applied to Pigeonpea

Over the past 5 years ICRISAT, in partnership with TechnoServe, has been using sub-sector analysis to identify critical constraints to growth in the pigeonpea sub-sector, and design interventions to develop business opportunities that will drive commercialization of rural enterprises, including smallholder farmers. The tool has helped provide a structured overview of the pigeonpea sub-sector - from research and extension to farmers and market intermediaries - identifying business opportunities that can lead to the creation of wealth in niches where rural households are likely to have a competitive advantage.

This paper describes our formative experience with the use of this tool in Tanzania, Mozambique, and Kenya. Our limited experience with using sub-sector analysis implies that it might be too early to assess the household level impacts resulting from its application. Nonetheless, we have learnt some early lessons that should help define and develop interventions that will lead to the creation of profitable and sustainable business enterprises.

In Tanzania the sub-sector analysis showed that bold, cream-colored pigeonpeas grown in northern Tanzania are highly sought after in European markets, where they attract premium prices (TechnoServe 1998a). However, this market has higher quality standards than the traditional Indian market. The analysis suggested that the most cost-effective interventions would be (i) giving farmers access to pigeonpea varieties with the desired market characteristics, (ii) better organization of domestic marketing. At the village level, interventions focused on providing smallholder farmers with improved seed that satisfied market standards, and organizing farmers into groups that are provided training to produce, clean, and grade the finished product. These farmer groups were linked directly to exporters who were assisted to get forward contracts with European buyers. A business plan was developed with an exporter to facilitate and expand purchases from farmers. TechnoServe helped the exporter mobilize finance by providing a loan guarantee on working capital to commercial banks.

In Mozambique the sub-sector analysis identified opportunities for seasonal trade to India from May to Sep, when pigeonpea supplies from domestic production and imports were at their lowest level and prices were highest (TechnoServe 1998b). Project interventions targeted delivery of improved short-duration varieties to the Indian market during this period. But these varieties are highly susceptible to insect pests, so a partnership was formed with cotton companies to integrate short-duration pigeonpea into the cotton production system. The result was a cotton-pigeonpea rotation system. Because the cotton companies provided inputs (seed and insecticides) farmers were able to apply cotton pest control measures on pigeonpea. This addressed the pest problem and allowed the cultivation of a variety that exploited the seasonal niche in Indian markets. TechnoServe arranged visits from overseas and domestic buyers and processors so that they could assess the market characteristics of the improved varieties and develop market linkages. Business plans were developed for enhancing production and export of the crop, with additional support provided for seed multiplication, input supply, and trade financing.

The interventions resulting from the sub-sector study in Kenya were primarily technological interventions that focused on improving consistency in the supply of vegetable pigeonpea (Freeman et al. 1998). This would strengthen the capability of the established horticultural industry to supply high quality pigeonpea products to markets in Europe year round. Samples of improved pigeonpea varieties were sent to buyers in Europe to assess market acceptability. Varieties that the market rated highly were multiplied and are being grown by large numbers of smallholder farmers for the high-value export market.

Lessons from Application of Sub-Sector Analysis

Our experience to date shows that developing an understanding of the pigeonpea sub-sector is a critical step in getting an accurate representation of its structure. The depth of this understanding has implications for the types of interventions developed and the probability that they will create wealth that leads to self-sustained growth for the rural poor.

A key step was to understand the nature of constraints to growth in the pigeonpea sub-sector. All the sub-sector studies described above included constraint analyses that focused on constraints in storage, marketing, transportation, processing and how they contributed to inefficiencies in the marketing system. Earlier studies have included analysis of constraints arising from the regulatory, institutional, and policy environment in which producers and market intermediaries operate. Rarely do these studies give serious consideration to the specific institutional arrangements that determine the production and exchange of commodities. Our experience, however, suggests that the institutional environment in which production and trade occurs as well as the specific institutional arrangements governing economic activities impose significant transaction costs that constrain market access and commercialization for most smallholder farmers. Our case studies in Tanzania, Mozambique, and Kenya provided evidence of high levels of transaction costs that are seldom accounted for in the development of interventions to improve market access and enhance commercialization in the pigeonpea sub-sector. For example:

- Market intermediaries rarely have key information on price, major market outlets, seasonal requirement, market product specifications or quality standards. The cost of acquiring such information is high, preventing many smallholder farmers from using such information to make production and investment decisions.

- Rural assemblers face high opportunity cost of time collecting small volumes of product from large numbers of producers scattered across rural areas
- Many producers continue selling to particular market intermediaries even when they are dissatisfied with the service because they cannot find an alternative market outlet or because the cost of finding and/or negotiating an alternative buyer is too high.
- The practice of deliberately mixing grain with foreign objects such as stones and selling the mixture as grain is widespread because the market does not distinguish among products - price is based on Fair Average Quality (FAQ), even though final markets distinguish the commodity on the basis of quality differences.
- Most market intermediaries rely on their own funds to finance their trading activities. Trading credit is often not available because lenders either find it difficult or expensive to assess creditworthiness. This high cost is reflected in widespread failures of credit markets in rural areas.
- Market intermediaries prefer quick cash turnover even though they could hold stock and get better prices. This is due to uncertainty about demand, product quality, and the conditions of trading.

What difference does all this make? For one, it allows us to challenge conventional beliefs about agricultural marketing, and the reasons why the sub-sector has responded sluggishly to commercial opportunities. Rather than blame unscrupulous traders exploiting poor smallholder farmers, it calls attention to the high cost of information and missing markets. These examples show that different types of transaction costs condition production and marketing relations among different agents in rural areas. And they might not be trivial. We did not directly measure transaction costs or assess their impact on improving market access for pigeonpea. Nonetheless, the case studies provide strong anecdotal evidence that these costs can be even more important than market prices or inefficient distribution systems in explaining low adoption of improved technologies by smallholder farmers.

The general lesson is that markets interact through many channels besides prices and incomes. The pervasiveness of high transaction costs in rural markets has implications for development strategies to improve market access and promote commercialization in the pigeonpea sub-sector. In the past, interventions focused on technological solutions and the development of business plans. Our studies, however, imply that greater emphasis should be placed on innovations that foster transparency in markets and institutions in order to reduce transaction costs in ways that will improve the competitive position of smallholder farmers and other market intermediaries.

Conclusions

This paper reviewed the experience of ICRISAT in partnership with TechnoServe in applying sub-sector analysis to the pigeonpea sub-sector. Application of this tool improved our understanding of the structure and dynamics of the sub-sector. But enough consideration has not been given to the different types of transaction costs faced by smallholder farmers and other market intermediaries in rural areas.

Consequently, business plans and other technological interventions resulting from the use of sub-sector analysis have not fully integrated the incentives (or lack thereof) that motivate farmers and other market intermediaries to respond to opportunities for commercialization. If this is the case then development practitioners should incorporate methods for measuring transaction costs, either directly or indirectly, in sub-sector analyses. In order to determine the incentives needed for producers and other market intermediaries to participate in any given sub-sector, it is necessary to accurately assess transaction costs - monetary and non-monetary - as well as the more discernible costs in production and distribution. The reality is that farmers and other market intermediaries include transaction costs, consciously or unconsciously, in addition to price parameters when making production and marketing decisions. It is therefore not surprising that the optimistic projections on supply response in our business plans have not materialized. Thus, if we are serious about building the competitive advantage of smallholder fanners and sustainably creating wealth in rural areas we should look more closely at the realities of costs and returns in rural areas.

References

Freeman, H.A., Jones, R.B., Silim, S., and Ochere, M. 1998. The pigeonpea sub-sector in Kenya. PO Box 39063, Nairobi, Kenya: ICRISAT (limited distribution).

Haggblade, S.J. and Gamser, M.S. 1991. A field manual for sub-sector practitioners. Washington, DC, USA: The GEMINI Project, United States Agency for International Development (USAID). 92 pp.

TechnoServe Inc. 1998a. Pigeonpea sub-sector study in northern Tanzania. Arusha, Tanzania: TechnoServe (limited distribution).

TechnoServe Inc. 1998b. Sub-sector report - pigeonpea. Nampula, Mozambique: TechnoServe (limited distribution).

Business Principles for Pigeonpea Market Linkage

G Kunde[1]

Introduction

In a gathering such as this, among papers such as you have heard, a presentation of this type needs to made with a hefty dose of humility. It is not the result of hard experimental data with a rigorous control group, nor does it demonstrate sophisticated statistical analysis. Scholarship cannot be claimed, and there is no point in pretending to belong among such peers.

Rather, what is offered are some reflections based on experience in doing business under similar conditions. What TechnoServe brings is a case study that may have some lessons to offer for the development of pigeonpea programs in the region, if they intend to address the issue of commercial sustainability. It is the examination of a program looking at the components, the constraints, and the solutions in order to distil from the experience certain principles, which appear to be applicable to pigeonpea. The exercise may be similar to an examination of history in order to improve contemporary decisions. One must be careful not to make the overlay too bold, but there is still something to be gained from the exercise.

The Case Study

The case referred to occurred over the past 2 years as part of TechnoServe's portfolio of agribusiness development. It began by facing up to the facts that things were not going well. Rural agricultural producers were not being paid after delivery to the processor. As this outlet for farmers collapsed, there was no alternative outlet for their production. So an alternative was established - but then this link began showing symptoms of business mortality.

The farmer's product that was passing through this intermediary was not being properly handled, so spoilage losses and rejections were creating financial losses that were threatening its survival. Operations limped along, barely surviving from month to month, when power problems necessitated the purchase of a generator. Delivery problems with the small town water system added other unplanned costs. It was the old pattern - handling costs were high and revenues were too low. Between the farm gate and the enterprise that was processing and packaging the product for the consumer, quality was not being assured.

In the office things were not much better. Delivery and shipment records were flawed. Expense accounting was available, but behind. Monthly financial statements did not reveal accurately the status of the operation - losses would only be known when there was no money to pay a bill. Typical of rural enterprises, perhaps, but hardly adequate for future sustainability.

1. Country Director, TechnoServe Inc., PO Box 14821, Nairobi, Kenya

In short, the problem was a dysfunctional linkage between the fanner (who was providing a decent product) and the processor (who was willing to pay a market price for it).

At this point TechnoServe looked at the situation squarely and implemented a remedial strategy. The senior staff member in charge temporarily moved to the site. The manager and accountant were replaced. A quality control system was put in place with product testing to ensure that products from the farm were acceptable and not mixed with foreign material to expand quantities. An external accounting firm was brought in to put in place a system that would meet minimal business standards. What needed to be done was no mystery, and certainly not very high tech. It just needed to be implemented, and done comprehensively.

Within 6 months the results began to show. The testing program at the plant-loading department turned away inferior products, and soon farmers learned to bring what was acceptable. A generator was installed to guarantee power to reduce spoilage. The record system meant that farmers were assured of being paid accurately and on time. The accounting system demonstrated the profitability each month and revealed changes in revenues or expenses.

This rural enterprise today operates on a 2% to 3% net profit, pays approximately 2000 farmers about 6-7 million KSh per month, and supplies a processor daily with a product that eventually finds its way to satisfied consumers in Nairobi. In spite of the current state of country's economy the entire district is showing the affect of the $1 million that entered its economy in the past 12 months.

The product has been left unnamed until now, so that we could focus on the commercial business dynamics. It is milk. For our purposes here it is not the product that is important, it is the commercial principles for sustainability that are vital. Some of these may be applicable to the pigeonpea industry, and they are offered briefly for consideration.

Essential Principles for Agricultural Commercial Sustainability

1. The market is the magnet that pulls farm production

Once we start to consider producing for sale, rather than for rural farm subsistence and barter, we ignore the market at our peril. Similar to milk there is a reasonable local market for this crop - processed, dried, and fresh - that is not being satisfied. Like the regional market for UHT milk, there is also a market potential for processed pigeonpea in neighboring countries. Unlike our case there is also an export market for the crop, provided certain quality and quantity requirements are met.

This market magnet principle is well known. Various studies have documented the Indian market window and the European ethnic demand, in addition to the cross-over popularization that is part of the overseas trends in eating habits.

So why do we see so little impact of the market at farm level? The answer lies in the second, third, and fourth principles.

2. Bulking is the pipeline that links farm production to the market

This could have been stated with a focus on infrastructure, but that gets us bogged down in those parts of the infrastructure that do not work very well. It is better to state it from the case study in a manner that identifies a key link in the commercial chain, which we can in practice address.

For pigeonpea to move from farm gate to the processor, or exporter, there needs to be a bulking facility based in the rural areas. It can start, perhaps, the way a cooling plant starts - by collecting the product in smaller quantities. In the case of milk, bulking is done in cans. It may be possible to bulk pulses in sacks and small truckloads, before bulking the product in godowns or large trucks. At some point (for dried pigeonpea) the business would adopt significant efficiencies and cost-saving measures to handle the crop like a commodity. If pigeonpea is graded before it is accepted from the farmer, and then cleaned at the bulking station, the value added increases still further.

All this leads to the possibility that such an operation could be a sustainable and profitable rural-based enterprise. There are indications that processors and exporters are willing to pay a premium price for a product that meets quality standards and is delivered according to contracted schedule.

3. Increased productivity rests in the hands of the farmer

One of the lessons from the dairy industry is interesting here. Without a market, yields and inputs are not important. Once the farmer is in touch with the market, then higher yields mean more money in his pocket, which in turn gives him the capacity to purchase inputs that will further increase those yields.

Thus, a non-leaking pipeline to the market becomes a means for transferring agronomic improvement back to the farm. Extension services, improved seed, and fertilizers can be channeled to progressive farmers because they have the motivation of the market and the means from their revenues. It is even possible to link a credit facility to the bulking plant since purchases by the farmer can be deducted from the farmer's account before he or she is paid.

While all this is logical and appealing, we must add a realistic note of caution. Hence the final principle.

4. Product and financial flows must be profitably managed

This is one of those statements that appear too obvious. Maybe it should be rephrased: Product and financial flows are difficult to manage profitably. If, as they say, "the devil is in the details", then it is certainly true here.

Profitable enterprises dealing postharvest with pigeonpea are similar to successful farms. It is necessary to do everything right. The margin for serious error in such enterprises is very thin. With milk one 12,000-liter tanker truck rejected can cost the month's profit. Even though pigeonpea is not that perishable, the margins between purchase price to the farmer and sale price to the processor are not large enough to absorb either losses from poor handling or financial management deficiencies.

From the outset any attempt to intervene in the commercial chain must be analyzed carefully according to profit-making criteria. Then a trial enterprise could be established to observe how the actual operations function in practice. Such an approach is similar to field trials, for if this experience in the soil of commercial reality is successful then others will invest their own resources.

I trust that even though this does not qualify as a scholarly paper, it might shed some light of one aspect of the development of this industry.

Discussions - Marketing and Enterprise Development

Marketing

Research programs may need to consider reorienting their work toward development of commercially valuable pigeonpea varieties with characteristics of commercial value, e.g. large white seeds, attractive green pods with good shelf life. The export market is growing rapidly. For example, Everest Ltd in Kenya exports about 1 ton per week of fresh green peas to the UK. There is also a large potential market for frozen peas.

Apart from specific varietal quality traits, researchers need to consider adaptation (photoperiod, temperature), and thus develop varieties that can be grown in specific areas for specific markets, which may require peas or grain to be shipped during a specific period.

Market development will involve an element of risk. Since a market does not yet exist in many parts of the region, potential size is hard to estimate - farmers will need to take the risk of entering an unknown market, with the expectation that it will grow sufficiently quickly to absorb the increased production. NGOs and other organizations need to identify measures to minimize the risk of exposure by smallholder farmers. In addition to export markets, there is a large untapped market within the region. For example, in Uganda and other countries, maize consumption has grown from very low levels 40-50 years ago, to being the dominant cereal consumed today. Tastes can be made to change with aggressive promotion, as was done for maize.

The critical constraint to improved marketing may be rural assembly, i.e. collection of small quantities from individual farmers and assembling large quantities at a single point to attract wholesale buyers. An informal collection/assembly system does exist in rural areas, and can be strengthened and used to stimulate marketing.

Transport costs

Price advantages are influenced by several factors including yield, number of growers (total output from a given area), and transport costs. Transport costs are often the decisive factor, and must be clearly factored into any technology exchange or commercialization strategy.

Country Experiences and Opportunities

On-Station Research, Technology Exchange, and Seed Systems for Pigeonpea in Tanzania

J K Mligo[1], F A Myaka[1], A Mbwaga[1], and B A Mpangala[2]

Introduction

Pigeonpea is an important grain legume crop grown by smallholder farmers in Tanzania. The major production areas are Southern Zone (Lindi and Mtwara regions) and Northern Zone (Arusha and Kilimanjaro regions, and especially Babati district in Arusha). In the Eastern Zone (Coast, Dar es Salaam, Tanga, and Morogoro) pigeonpea is important as a green vegetable.

Pigeonpea is mostly grown rainfed, and normally as an intercrop, mainly with maize and to a lesser extent with sorghum, cassava, and sweet potato (Mbowe and Maingu 1987). In this cropping system farmers grow traditional tall, long-duration (9-10 months) landraces with bold white seeds. However, yields are very low (0.3-0.5 t ha^{-1}) (Mligo and Myaka 1994).

The major constraints include: lack of appropriate improved high-yielding varieties, lack of quality seed, insect pests (pod borers, pod-sucking insects), diseases (mainly fusarium wilt), poor production practices (e.g. low plant densities), frequent droughts, and poor marketing infrastructure.

The main objectives of the Tanzanian pigeonpea improvement program are, therefore, to

- Introduce and evaluate short-duration pigeonpea (with bold white seeds) with potential for multiple harvests
- Evaluate medium-duration lines as possible replacements for long-duration pigeonpea, e.g. in drought-prone areas
- Develop high-yielding, long-duration pigeonpea to improve the cropping system
- Screen for fusarium wilt resistance in all maturity groups
- Develop and disseminate superior agronomic practices
- Identify and alleviate socioeconomic constraints to production
- Develop a sustainable seed production system
- Conduct on-farm research to create awareness and transfer improved technologies to farmers.

This paper describes recent progress made in three areas - on-station research (multilocational trials), on-farm research (technology exchange), and seed systems.

1. Ilonga Agricultural Research Institute, Private Bag Kilosa, Tanzania
2. Naliendele Agricultural Research Institute, PO Box 506, Mtwara, Tanzania

Multilocational Variety Evaluation

The breeding program made use of breeding lines developed by ICRISAT. Short-, medium, and long-duration genotypes were tested for adaptability, yield, seed quality, disease and pest resistance, and acceptability. Considerable effort was spent on short-duration genotypes, especially in Eastern Zone, because this was a new cropping system in Tanzania and showed promise even in areas where pigeonpea was not traditionally grown.

Short-duration genotypes

Short-duration genotypes were introduced from ICRISAT in the late 1980s. Trials were conducted in the 1986/87 season at three locations in Eastern Zone (details in Maingu and Mligo 1991). The best performers were two brown-seeded lines, ICPL 87 and ICPL 146. Subsequently, in collaboration with the African Development Bank/ICRISAT Pigeonpea Project, multilocational trials were conducted for several seasons (see Mligo and Myaka 1994, Mligo 1995, 1996). Results showed that short-duration genotypes were widely adapted and gave yields of 1.0-1.7 t ha^{-1}, but performed best at locations with warm temperatures (mean of 25°C), where they yielded 1.7-3.0 t ha^{-1}. These are low-altitude areas (0-600 m), i.e. most of the Eastern Zone and areas along the coast. The highest yielder was ICPL 86005, again a brown-seeded genotype. Since most farmers prefer white-seeded types, further work was needed. A number of promising white-seeded genotypes were found, of which two were selected - ICPL 87091 (white) and ICPL 86005 (brown). These selections were further tested on-farm to give farmers the opportunity to select a variety(ies) they prefer and enable researchers to understand farmers' selection criteria. Eventually ICPL 87091 was identified, particularly for cultivation in Eastern Zone. This variety has now been released under the name Komboa - the first pigeonpea release in Tanzania.

Medium-duration genotypes

Evaluation of medium-duration genotypes started in the early 1990s, when a number of genotypes introduced from ICRISAT were evaluated at several locations (results reported by Mligo and Myaka 1994, Mligo 1995, 1996). ICP 7035 B gave high yields, but was rejected due to its brown color. A slightly white-colored version of ICP 7035 was developed, but again rejected due to its small seed size. Further evaluation of new genotypes continued. Recently, several promising medium-duration genotypes have been identified, including: ICEAP 00557, ICP 12734, ICEAP 00554, ICEAP 00068, and ICEAP 00550. Their grain yields were 1.0-1.6 t ha^{-1} (Table 1). These genotypes are now under on-farm evaluation in the Southern Zone (ICEAP 00557,00554,00068) and Eastern Zone (ICEAP 00068).

Other studies on medium-duration genotypes included identification of high-yielding lines tolerant of pod borers in a range of environments in the Southern Zone. Pod borers are the major insect pests of pigeonpea and farmers normally do not spray; hence the importance of genetic resistance. In the 1998/99 season new genotypes were received from ICRISAT-Nairobi and evaluated under sprayed and unsprayed

Table 1. Performance of medium-duration pigeonpea genotypes at Donga (506 m) and Naliendele (120 m), 1998/99.

	Ilonga			Naliendele		
Genotype	Days to 50% flower	Days to 75% maturity	Grain yield (t ha^{-1})	Days to 50% flower	Days to 75% maturity	Grain yield (tha^{-1})
ICEAP 00068	94	160	1.0	146	181	1.0
ICEAP 00073	107	177	1.1	151	188	1.3
ICEAP 00540	102	151	0.9	146	182	0.9
ICEAP 00550	91	166	1.2	146	178	0.9
ICEAP 00551	91	157	0.9	146	181	0.9
ICEAP 00553	94	164	0.9	148	181	1.1
ICEAP 00554	98	160	1.2	146	172	1.0
ICEAP 00557	98	159	1.3	138	188	1.6
ICP 11298	106	164	0.7	149	170	1.3
ICP 12734	88	161	0.9	146	168	1.0
ICP 6927	89	165	0.7	131	182	1.0
ICEAP 00850	90	168	1.0	138	177	1.2
ICEAP 00911	91	176	1.2	138	154	1.2
ICPL 87051	88	169	0.7	114	184	0.8
Local check	113	169	0.3	148	178	0.9
Mean	96	164	0.8	142	178	1.0
SE±	1.33	1.31	82.03*	1.6***	1.7**	48.47 ns
CV(%)	6.23	3.39	33.86	5.0	5.0	31.2

conditions at Naliendele and Nachingwea research stations. There were significant differences between genotypes at both locations. However, grain yields from sprayed plots at Naliendele were not very different from the unsprayed plots, indicating low insect activity that year. ICEAP 00902, ICP 1811-E3, and ICEAP 00772 gave the highest yields under sprayed conditions, 1.7-2.1 t ha^{-1}. Under unsprayed conditions ICEAP 00907 and ICEAP 00778 (1.6-1.8 t ha^{1}) gave the highest yields.

ICEAP 00902 performed well at both locations under sprayed and unsprayed conditions, indicating some tolerance to pod borers. However, further testing is needed before final conclusions can be drawn.

Long-duration genotypes

Multinational trials of long-duration pigeonpea started in the 1992/93 season, but to date there has not been much progress in identifying good performers. Grain yields in most seasons have averaged about 1 t ha^{-1} with complete failure in poor seasons (Mligo and Myaka 1994, Mligo 1995, 1996). The low yields were due to terminal drought stress, indicating that we were not working with the appropriate genotypes. However, some of the newest genotypes have shown some promise, with yields of 1.3-1.8 t ha^{-1}. These include: ICEAP 00020,00040,00790,00561 and ICP 9145 (Table 2). The first two are being tested on-farm in the Northern, Central, and Eastern Zones.

Table 2. Performance of long-duration pigeonpea genotypes at Naliendele (120 m), 1998/99.

Genotype	Days to 50% flower	Days to 95% maturity	Grain yield (t ha^{-1})	100-seed mass (g)
ICEAP 00020	157	186	1.3	17
ICEAP 00040	162	185	1.8	20
ICEAP 00053	157	189	1.4	16
ICEAP 00528	153	181	1.4	16
ICEAP 00560	162	196	1.2	17
ICEAP 00561	156	184	1.6	17
ICEAP 00790	151	182	1.7	14
ICEAP 00809	163	189	1.2	18
ICEAP 00932	165	195	1.4	19
ICEAP 00933	155	185	1.4	17
ICEAP 00934	151	182	1.3	14
ICP 13076	153	183	1.0	17
ICP 9145	157	183	1.4	15
ICEAP 00950	156	184	1.1	14
Local check	151	183	1.5	17
Mean	156.5	185.9	1.4	16.4
CV(%)	3.1	3.1	26.9	8.4
LSD (P = 0.05)	8.3	ns	ns	2.3***

Germplasm screening for fusarium wilt resistance

In Tanzania, the pigeonpea diseases of economic importance include fusarium wilt, leaf spot, powdery mildew, *Macrophomina* stem canker, and rust (Kannaiyan et al. 1984). In surveys conducted in Kilosa district in 1988, it was observed that wilt was a major constraint, with incidence ranging from 10% to 96 % on farmers' fields (Mbwaga 1988).

Widespread wilt damage was also reported in 1995. Disease incidence ranged from 10 to 50% in farmers' fields in Morogoro, Coast, and Tanga regions. Similar incidence was reported in the major pigeonpea-growing areas of Tanzania, which include Mtwara and Lindi. A screening program for fusarium wilt resistance was therefore initiated at the Ilonga Agricultural Research Institute, using short-, medium-, and long-duration genotypes from ICRISAT-Patancheru, India.

Mbwaga (1995) reported that all the short-duration lines in the trial were susceptible to fusarium wilt when they were planted in a hot spot in farmers' fields. In a later screening trial, one short-duration genotype ICP 83024 was found to have moderate resistance, with disease incidence of 21.9% (Mbwaga 1996). However, studies conducted in 1998 showed that this line too was susceptible. Wilt incidence was relatively low in 1998, probably due to El Nino rains which continued throughout the growing season (wilt is associated with dry spells). Five genotypes were considered to be resistant, with less than 15% wilt. ICEAP 00040 showed 0% wilt

Recent screening for wilt resistance looks for resistance coupled with adaptation, yield, and farmer acceptability. This approach was started in 1999 when 14 long-duration lines from ICRISAT-Nairobi plus a local check were planted at a fusarium hot spot at Ilonga Research Institute. Wilt incidence was generally low during the season, ranging from 39.9% in the local variety to 0% in ICEAP 00040 (Table 3). For the past three seasons ICEAP 00040 has consistently shown the lowest fusarium wilt incidence, along with other desirable characteristics such as large seeds. On-farm testing in the Northern Zone has shown it is highly acceptable to farmers. It appears to be superior to the earlier identified wilt-resistant genotype ICP 9145 (which is actually moderately resistant) in terms of grain yield and seed size. Plans are underway to propose the release of ICEAP 00040.

Agronomy Research

Short-duration pigeonpea spacing studies

When short duration pigeonpea germplasm was introduced in Tanzania from ICRISAT, ICRISAT recommendations on spacing (ICRISAT 1985, 1986) were adopted, i.e. very closely spaced rows (30 x 10 cm). However, small-scale farmers in Tanzania will not accept very narrow spacings because closely spaced rows are difficult to weed, especially when a hand hoe is used. An experiment was therefore conducted at Ilonga (wet environment) and Hombolo (dry environment) in 1993,1994, and 1995. The results were reported by Mligo and Myaka (1994) and Myaka and Silim (1997). Response of short-duration pigeonpea to inter-row spacing was different in the two environments; different environments therefore

Table 3. Performance of pigeonpea genotypes in the wilt resistance screening trial, Ilonga, 1999.

Genotype *	Days to 50% flower	Wilt incidence (%)	Grain yield ($t\ ha^{-1}$)	100-seed mass (g)
ICEAP 00020	115	10.9	2.3	23.1
ICEAP 00040	113	0.0	1.9	25.8
ICEAP 00053	123	5.6	2.0	19.2
ICEAP 00528	112	3.5	1.9	19.1
ICEAP 00560	105	6.7	2.1	17.7
ICEAP 00561	106	4.2	1.9	18.4
ICEAP 00790	105	31.7	1.6	18.3
ICEAP 00809	108	18.2	1.7	17.5
ICEAP 00932	111	15.3	2.0	22.7
ICEAP 00933	109	16.1	2.2	20.7
ICEAP 00934	115	5.9	2.2	24.4
ICP 13076	105	16.9	1.6	23.0
ICP 9145	114	11.3	1.7	18.2
ICEAP 00950	122	2.0	2.7	19.0
Local check	-	30.9	-	-
Mean	104.3	12.0	1.9	
SE±	4.3	1.9	0.1	

* Number of plants: 16-19 plants of each genotype

require different spacing recommendations. The experiment also showed that in wet, low-altitude environments, inter-row spacing as wide as 60 cm could be used without significant yield reduction (Myaka and Silim 1997).

Intercropping studies

Intercropping short-duration pigeonpea with sorghum. An experiment was conducted to determine the effect of intercropping on overall productivity. Sorghum variety Tegemeo and short-duration pigeonpea ICPL 86005 were intercropped at various patterns at Ilonga and Hombolo in 1989, 1990, and 1991. The results were reported by Myaka (1994).

New cropping system for short-duration pigeonpea. Since short-duration pigeonpea was a new crop, it was important to determine the optimal intercropping pattern. ICPL 86005 was intercropped with cowpea or early-maturing maize at different patterns in the short rains at Mlingano in 1994/95. During the long rains, it was intercropped with either cotton or late-maturing maize. Results were reported by Myaka (1996). Pigeonpea intercropped with early-maturing maize during the short rains followed by a ratoon crop intercropped with cotton in the main rains produced high returns. ICPL 86005 showed poor ratoonability. For the new system to succeed, a short-duration pigeonpea with good ratooning ability needs to be identified (Myaka 1996).

Insect Pest Studies on Short-Duration Pigeonpea

Short-duration pigeonpea is susceptible to insect pests. Two studies on pest control have so far been conducted:

- Effect of sowing date and insecticide application on yield
- Spray schedule for short-duration pigeonpea.

Effect of sowing date and insecticide application on yield

Trials were conducted at Ilonga and Gairo in 1993,1994, and 1995 (see Mligo and Myaka 1994, Myaka 1995,1996). Late sowing reduced pod bores but increased the incidence of pod-sucking bugs. The reduced pod borer activity was due to lower temperatures (correlation analysis showed that 93% of the variation in pod borer damage could be accounted for by variation in minimum temperature). However, reduced borer activity coincided with a period of terminal drought, and thus was not reflected in the final yield. Therefore this advantage could only be useful to valley bottom crops that survive under residual moisture.

Spray schedule for short-duration pigeonpea

Insect pests are most critical during the reproductive stage of the crop. Spraying is recommended starting at flowering, continuing at 10-day intervals throughout the reproductive stage. Due to the long pod-filling period, up to four sprays are needed Most farmers

Table 4. Effect of spray schedule on pod borer and pod-sucking bug damage on pods of short-duration pigeonpea, Ilonga, 1997.

Spray schedule	No. of pods per 20 pods with pod borer holes, square root transformation	No. of pod borer holes per 20 pods. square root transformation	% pod-sucker damage arc sine transformation
1	3.6	5.2	5.3
2	0.5	0.5	2.8
3	1.5	2.1	2.2
4	0.7	1.2	2.6
5	0.6	0.9	2.5
6	2.0	3.1	2.7
7	0.6	0.6	2.0
SE±	0.26**	0.36**	0.22**

Spray schedule:

No insecticide spray (control)

3 sprays starting at 50% flowering, then at 10-day intervals

2 sprays starting at 50% flowering, then after 10 days

2 sprays starting at 50% flowering, then after 20 days

2 sprays starting at 10 days after 50% flowering, then after 10 days

1 spray at 50% flowering

1 spray at 10 days after 50% flowering

cannot afford this; and in any case repeated sprays may be uneconomical. An experiment was therefore initiated in 1997 to develop a spray regime with fewer sprays by targeting the most critical stage. ICPL 87091 was used with 1 to 3 sprays at different times (Table 4). Damage due to pod borers and pod-sucking bugs was assessed at the podding stage 75 days after planting. Data were transformed as appropriate and subjected to analysis of variance.

There was highly significant difference between treatments ($P<0.01$), for damage due to both types of pest. Insecticide application significantly reduced damage by both pod borers and pod-sucking bugs (Table 4). Three sprays at 10-day intervals was me most effective against pod borers, but did not show any advantages over other treatments in reducing damage by pod-sucking bugs.

The results show that iftwo sprays are used, the first spray should be delayed until 10 days after 50% flowering. If only a single spray is used, it should be done 10 days after 50% flowering.

On-Farm Research

On-farm research activities are described in detail by Lyimo and Myaka elsewhere in these proceedings.

Pigeonpea Seed Production

The pigeonpea seed production system in Tanzania is similar to that for other crops. Once a variety is released by the Variety Release and Seed Production Committee of the Ministry of Agriculture and Cooperatives, variety maintenance is the responsibility of the breeder of the institution that developed the variety. Multiplication is normally assigned to one of the four foundation seed farms. This foundation seed is supposed to be purchased by the Tanzania Seed Company (Tanseed) which contracts farmers to produce certified seed for sale to farmers.

However, Tanseed has difficulty producing adequate quantities of certified seed. This, together with a poor distribution system, has led to unavailability of seed and thus poor adoption of improved varieties of many crops. The Ministry of Agriculture then allowed private seed companies to operate, but this has not solved the problem because private companies focus on large-volume crops such as maize. They are not interested in handling small quantities of self-pollinated crops such as pigeonpea.

One solution is to promote community-based seed production and distribution. High quality seed of improved released varieties of pigeonpea could be produced on-farm by farmer groups that later could be registered as seed grower associations or cooperatives. Rural primary schools are another possibility - such schools are found at least every 70-100 km, and could be encouraged to become seed production and distribution centers. This approach has worked well with sorghum varieties in Central Zone, and could be extended to pigeonpea.

Plans are underway for a pilot project in the Central Zone, producing pigeonpea seed on a commercial basis through a community-based production and distribution system. This project will tie in with sorghum seed production. However, implementation will have to wait until varieties adapted to Central Zone are identified and released. According to Tanzanian law, quality and purity testing by the Tanzania Official Seed Certification Agency (TOSCA) is mandatory before seed can be sold. And TOSCA handles varieties only after they have been released and registered.

Even with a seed system in place, the success of pigeonpea promotion will depend on the development of markets for surplus pigeonpea obtained from increased production. Thus linkages with traders will have to be established.

Acknowledgments

We thank ICRISAT-Nairobi for providing the National Grain Legume Research Program with improved pigeonpea genotypes and for funding evaluation of these genotypes through the African Development Bank-ICRISAT Pigeonpea Project. Many thanks to staff from the various research institutes who helped conduct the research reported in this paper.

References

ICRISAT. 1985. Annual Report 1985. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.379 pp.

ICRISAT. 1986. Annual Report 1986. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 367 pp.

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

Maingu, Z.E. and Mligo, J.K. 1991. Pigeonpea production systems and research in Tanzania. Pages 83-90 *in* Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop, 25-27 Jun 1990, Nairobi, Kenya (Singh, L., Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., eds). PO Box 39063, Nairobi, Kenya: EARCAL program, ICRISAT.

Mbwaga, A.M. 1995. Fusarium screening in Tanzania. Pages 101-103 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Mbwaga, A.M. 1996. Fusarium screening in Tanzania. Pages 80-82 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Mbwaga, A.M. 1988. Grain legume pathology in Tanzania, 1987/88 cropping season. Pages 66-68 *in* National Grain Legume Progress Report. Arusha, Tanzania: Ministry of Agriculture (limited distribution).

Mbowe, F.F.A. and Maingu, Z.E. 1987. Status of pigeonpea production in Tanzania. Paper presented at the ICRISAT Pigeonpea Scientists Meeting, 2-5 Jun 1987, Nairobi, Kenya.

Mligo, J.K. 1995. Pigeonpea breeding research in Tanzania. Pages 95-100 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Mligo, J.K. 1996. Progress in pigeonpea breeding research in Tanzania. Pages 67-79 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Mligo, J.K. and Myaka, F.A. 1994. Progress of pigeonpea research in Tanzania. Pages 51-58 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 25-27 Oct 1993, Bulawayo, Zimbabwe (Silim, S.N., Tuwafe, S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Myaka, F.A. 1994. Intercropping of short duration pigeonpea and maize in sub-humid low altitude areas in Tanzania. Pages 150-153 *in* Proceedings of the Africa Crop Science Conference, vol 1. Kampala, Uganda: Africa Crop Science Society.

Myaka F.A. 1995. Pigeonpea agronomy research in Tanzania: recent results and plans for the future. Pages 104-109 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Myaka, F.A. 1996. Progress on pigeonpea agronomy research in Tanzania. Pages 83-88 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning

Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Myaka, F.A. and Silim, S.N. 1997. Response of short-duration pigeonpea to inter-row spacing in low altitude wet and mid-altitude dry environments in Tanzania. Pages 805-808 *in* Proceedings of the Africa Crop Science Conference, vol 3. Kampala, Uganda: Africa Crop Science Society.

On-Station Research, Technology Exchange, and Seed Systems for Pigeonpea in Uganda

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Introduction

Pigeonpea is an important food legume in Uganda, especially in the northern and eastern parts; it is also grown in other parts of the country as a backyard crop (Areke et al. 1995, Obuo and Okurut-Akol 1995). It is grown mainly for its grain - whole seeds are eaten in green or dry form, or split peas are cooked to form a homogeneous paste (*dhat).* Pigeonpea is also important in the fanning system, enriching the soil when used in rotation or mixed cropping. The plant also provides fuelwood, animal feed, and construction material, and can serve as a windbreak to prevent soil erosion (Areke et al. 1995). The crop is not irrigated and is often intercropped with cereals (mainly millet) and groundnut (Ugen and Silim 1995, Areke et al. 1995).

Despite its importance and long history of cultivation in Uganda, pigeonpea production and productivity have remained low and restricted to the northern parts of the country. This is mainly due to lack of improved cultivars, shortage of seed, prevalence of pests and diseases, and lack of improved agronomic and postharvest technologies acceptable to farmers (Esele 1995, Areke et al. 1995, Ugen and Silim 1995, Silim Nahdy et al. 1994). Many farmers intercrop pigeonpea with millet but do not do it correctly. Pests are prevalent but chemical control is not used. Farmers grow low-yielding landraces that take 180-300 days to mature. Research work in Serere therefore aimed at addressing these constraints.

On-Station Research

Breeding lines from ICRISAT were evaluated for adaptation and yield in order to identify adaptable, high-yielding short- and medium-duration materials with acceptable attributes. Pest management trials were aimed at identifying lines that could tolerate pest attacks. The objective of cropping systems trials was to identify the best intercrop combination for short-stature pigeonpea lines and the optimum spatial arrangement for pigeonpea/millet intercrops.

Variety trials

Pigeonpea lines from three maturity groups (short-duration, early- to medium-duration, and medium-duration) were evaluated at SAARI in 1998 for yield and adaptation. In addition, 20 genotypes were evaluated under sprayed and unsprayed conditions to determine insect pest resistance. In each trial, a randomized complete block design was used with three

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replicates. Each plot consisted of 4 rows, 5 m long, but spacing was different for each maturity group. The trials - except for the unsprayed treatment in the insect resistance trial - were sprayed with insecticide three times to control pests at flowering, podding, and pod filling. No fertilizers were applied. Weeding by hoe was done thrice and plants thinned to one plant per hole. At maturity net plots were harvested. Data were subjected to analysis of variance (ANOVA) using Genstat 5.

Short-duration pigeonpea. Fourteen short-duration pigeonpea lines were evaluated. Spacing was 60 x 30 cm. ICPL 87091 was used as a control. There were no significant differences among the entries in emergence or in days to maturity. Flowering ranged from 56 to 61 days and maturity from 95 to 105 days. ICPL 86012 and ICPL 87105 (95 and 97 days) were the earliest to mature, while ICEAP 00336, ICPL 93027, and ICPL 93047 (105 days) were the latest to mature. Grain yields ranged from 1.2 to 1.9 t ha^{-1}. ICEAP 00535 gave the highest yield and ICPL 93047 the lowest. Most of the entries outyielded the control, ICPL 87091.

Early- to medium-duration pigeonpea. Eighteen early- to medium-duration pigeonpea lines were evaluated. Spacing was 100 x 50 cm. ICPL 87091 and Kat 60/8 were used as controls. All entries emerged in 6-7 days and flowered in 62-69 days. ICPL 87091 was the earliest and ICEAP 00436 the latest to flower. Maturity ranged from 103 to 118 days. Kat 50/3 (103 days) was the earliest and Kat 60/8 (118 days) the latest. The 100-seed mass ranged from 8.9 to 11.4 g. ICPL 87091 had the smallest seeds and ICEAP 00723 the largest. Grain yields ranged from 1.05 to 1.70 t ha^{-1}. ICEAP 00431 gave the highest yield - 38% more than ICPL 87091 and 25% more than Kat 60/8. ICEAP 00436 and ICPL 87091 (1.05 and 1.06 t ha^{-1}) gave the lowest yields.

Medium-duration pigeonpea. Fifteen medium-duration pigeonpea lines were evaluated. Spacing was 100 x 50 cm. The entries flowered in 75-93 days. The earliest to flower (75 days) were ICEAP 00540, ICEAP 00550, ICEAP 00553, and ICP 6927. ICEAP 00073 (93 days) was the latest to flower. Maturity ranged from 113 to 126 days; again ICEAP 00073 was the latest to mature (126 days). The highest yielders were ICEAP 00550 and ICEAP 00068, with 1.39 and 1.38 t ha^{-1} respectively. The lowest yield, 739 kg ha^{-1}, was obtained from ICP 11298.

Resistance to insect pests. Twenty pigeonpea lines were evaluated for performance under sprayed and unsprayed conditions. Chemical pesticide was sprayed thrice, at flowering, podding, and pod filling. Results are shown in Table 1. In the unsprayed treatment insect pests reduced grain yields considerably, but ICP 12734, ICEAP 00860, ICEAP 00902, and ICP 6927 performed relatively well, better than the control Kat 60/8. ICP 12734 performed well under both sprayed and unsprayed situations, with more than double the yield of Kat 60/8 in each treatment.

Pigeonpea cropping systems

Short-duration pigeonpea intercropping trial

ICPL 87091 was intercropped with beans, groundnut, greengram, and finger millet, with 9 treatment combinations: 4 sole crops and 5 intercrops, i.e. pigeonpea with each of these

Table 1. Grain yield (kg ha^{-1}) of 20 pigeonpea lines under sprayed and unsprayed conditions, SAARI, 1998.

Entry	Sprayed yield	Unsprayed yield
ICP 12734	2552	1510
ICP 6927	1975	1165
ICP 7035W	1198	471
ICP 87051	1906	971
ICEAP 00068	1640	335
ICEAP 00771	1113	298
ICEAP 00772	1998	1090
ICEAP 00775	1746	929
ICEAP 00778	1337	567
ICEAP 00902	2419	1275
ICEAP 00907	2104	823
ICEAP 00889	1642	906
ICEAP 00840	2238	1142
ICEAP 00860	2095	1231
Kat 60/8	1075	715
ICP 8102-5-51	1000	750
PPE 45	1817	518
ICP 1811-E3	1269	569
ICP 332	1825	731
ICP 8094-2-52	746	269
Mean	1725	813
SE±	603.1	399.9
CV(%)	35.0	49.2

crops. The plots were laid out in a completely randomized block design with three replications, size 5 x 4 m. The following spacings were used: pigeonpea 60 x 30 cm, beans 60 x 20 cm; greengram 60 x 30 cm, groundnut 60 x 5 cm, finger millet 60 x 5 cm.

Data were subjected to analysis of variance (ANOVA). Results obtained with the farmers' method (which was used as a control) were then compared with various intercrop combinations. The combinations were evaluated in terms of yield as well as Land Equivalent Ratios (LERs).

Results are shown in Tables 2 and 3. The highest pigeonpea yields were recorded from sole pigeonpea followed by the pigeonpea/greengram and pigeonpea/millet intercrops. The pigeonpea/groundnut intercrop gave the lowest yields. All intercrops gave LERs higher than one, indicating the yield advantage from pigeonpea intercropping. The high LER of the pigeonpea/beans intercrop suggests the suitability of ICPL 87091 as an intercrop with beans.

Pigeonpea/millet spatial arrangement intercropping trial

The study was conducted during the first rains of 1998 and 1999 using two improved released varieties. Pigeonpea SEPI-1 (Kat 60/8) was intercropped with finger millet Pese 1. Nine spatial arrangements were investigated:

1. Single rows of pigeonpea at 60 x 30 cm among broadcast millet
2. Single pigeonpea rows at 40 x 30 cm
3. Paired pigeonpea rows at 60 x 30 cm spaced 150 cm apart among broadcast millet
4. Paired pigeonpea rows at 40 x 30 cm spaced 200 cm apart among broadcast millet
5. Three pigeonpea rows at 60 x 30 cm spaced 150 cm apart among broadcast millet
6. Three pigeonpea rows at 40 x 30 cm spaced 200 cm apart among broadcast millet
7. Broadcast pigeonpea/millet intercrop (farmer practice)
8. Broadcast sole millet (farmer practice)
9. Sole pigeonpea at 60 x 30 cm (recommended method for sole pigeonpea).

Table 2. Yields from various sole and intercrop combinations, SAARI, first rains 1998 and 1999.

Treatment	Yield (kg ha^{-1}) in 1998		Yield (kg ha^{-1}) in 1999	
	Pigeonpea	Other crop	Pigeonpea	Other crop
Sole pigeonpea	1319		2548	
Pigeonpea/greengram	1062	250	1424	234
Sole greengram		404		320
Pigeonpea/beans	969	500	1472	200
Sole beans		1046		380
Pigeonpea/groundnut	718	162.8	1156	552
Sole ground nut		233.4		846
Pigeonpea/finger millet	926	646	1524	554
Sole finger millet		878		1070

CV and SED for yields in 1998 and 1999 were as follows:

	Pigeonpea		Beans		Greengram		Groundnut		Millet	
	98	99	98	99	98	99	98	99	98	99
CV (%)	28.4	17.1	29.2	8.3	32.6	30.9	11.6	24.8	19.6	27.5
SED	231.6	124	184.2	55.4	86.8	61.6	19.0	104.0	179.1	185.0

Table 3. Land equivalent ratios (LER) for different crop combinations, SAARI, first rains 1998 and 1999.

Treatment	LER in 1998			LER in 1999		
	Pigeonpea	Other crop	Total	Pigeonpea	Other crop	Total
Sole pigeonpea	1.0		1.0	1.0		1.0
Pigeonpea/greengram	0.81	0.62	1.43	0.56	0.73	1.29
Sole greengram		1.0	1.0		1.0	1.0
Pigeonpca/beans	0.73	0.48	1.21	0.58	0.53	1.11
Sole beans		1.0	1.0		1.0	1.0
Pigconpca/groundnut	0.54	0.70	1.24	0.45	0.65	1.10
Sole groundnut		1.0	1.0		1.0	1.0
Pigeonpea/finger millet	0.70	0.74	1.44	0.60	0.52	1.12
Sole finger millet		1.0	1.0		1.0	1.0

The experiment was arranged in a completely randomized block design with three replications, with plot size of 6 x 10 m. Pigeonpea was planted at a spacing of 60 x 30 cm and thinned to 1 plant per hole, giving an expected population of 55,556 plants ha^{-1}. The plants were protected against insect pest attack by four sprays of Dimethoate (400 g a.i. ha^{-1}). At crop maturity/drying, pods were harvested from a net plot of 4 x 8 m in each plot. The pods were dried and threshed and grain weight per plot measured to calculate grain yield in kg ha^{-1}.

Data were subjected to analysis of variance (ANOVA). Results from the farmers' practice (used as control) were compared with the new methods of plant spatial arrangement using Standard Error of Deviation (SED). LERs were also used for comparing different treatments. Results are shown in Tables 4 and 5.

Paired rows 60 x 30 cm spaced 150 cm apart among broadcast finger millet gave the highest grain yield per hectare, followed by single rows of pigeonpea at 60 x 30 cm among broadcast millet. The lowest yield was obtained from broadcast pigeonpea/millet. LER was highest in paired rows of 60 x 30 cm spaced 150 cm apart among broadcast millet. Broadcast pigeonpea/millet (farmer practice) gave the lowest LER.

Conclusions

Improved pigeonpea genotypes generally outyielded the local varieties (250-400 kg ha^{-1}) as was also reported by Areke et al. (1995). However, there is a need to repeat the trials to ensure consistency of performance in the improved lines. There were impressive individual plants from which single plant selections were made. These will be planted in Nairobi University, Makerere University, and SAARI for further evaluation.

Evaluation under sprayed and unsprayed conditions indicated that some lines have promise. The trials need to be repeated to confirm this promise. Genetic resistance to insect pests is particularly important to smallholder farmers, who cannot afford insecticides.

Normal farmer practice is to intercrop pigeonpea with cereals by broadcasting both crops. This makes it difficult to carry out pest control especially on pigeonpea. The new method of planting paired rows of pigeonpea among broadcast millet will not only increase yields but also make it easier to spray pigeonpea (increased yields in this system may make spraying cost-effective). However, farmer-acceptability of this system is yet to be tested.

Kat 60/8 and ICPL 87091 were released for cultivation in Uganda in 1999 as SEPI 1 and SEPI 2 respectively. SAARI earlier multiplied some seed of these varieties through contract farmers in Lira and Apac districts. This seed was distributed to farmers through AT Uganda and Sasakawa Global 2000. However, there is no established seed system for pigeonpea in Uganda. It is important to strengthen the informal seed sector in order to alleviate widespread seed shortages.

Acknowledgments

This work was supported by ICRISAT which provided both genotypes and funding for trials. Special appreciation to Prof. PM Kimani, University of Nairobi and Dr KB Saxena, ICRISAT-Patancheru for assisting to make single plant selections. NARO supported the

Table 4. Effect of spacing on yield of pigeonpea and finger millet, SAARI, first rains 1998 and 1999.

Treatment	Yield ($kg\ ha^{-1}$) in 1998		Yield ($kg\ ha^{-1}$) in 1999	
	Pigeonpea	Millet	Pigeonpea	Millet
Single pigeonpea rows at 60x30 cm among broadcast millet	976	582	774	600
Single pigeonpea rows at 40x30 cm	852	630	623	618
Paired pigeonpea rows at 60x30 cm spaced 150 cm apart among broadcast millet	1202	642	1010	654
Paired pigeonpea rows at 40x30 cm spaced 200 cm apart among broadcast millet	655	589	435	520
Three pigeonpea rows at 60x30 cm spaced 150 cm apart among broadcast millet	621	502	606	486
Three pigeonpea rows at 40x30 cm spaced 200 cm apart among broadcast millet	615	560	535	552
Broadcast pigeonpea/millet	580	486	480	460
Broadcast sole millet	–	797	-	874
Sole pigeonpea at 60x30 cm	1362	-	1545	-
CV (%)	30.7	25.5	27.2	22.6
SED	151.8	121.7	143.1	103.0

Table 5. Effect of spacing on land equivalent ratios (LER) of pigeonpea/millet intercrop, SAARI, first rains 1998 and 1999.

Treatment	LER in 1998			LER in 1999		
	Pigeonpea	Millet	Total	Pigeonpea	Millet	Total
Single pigeonpea rows at 60x30 cm among broadcast millet	0.72	0.73	1.45	0.50	0.69	1.19
Single pigeonpea rows at 40x30 cm	0.63	0.79	1.42	0.40	0.71	1.11
Paired pigeonpea rows at 60x30 cm spaced 150 cm apart among broadcast millet	0.88	0.81	1.69	0.65	0.75	1.40
Paired pigeonpea rows at 40x30 cm spaced 200 cm apart among broadcast millet	0.48	0.74	1.22	0.28	0.59	0.87
Three pigeonpea rows at 60x30 cm spaced 150 cm apart among broadcast millet	0.46	0.63	1.09	0.39	0.56	0.95
Three pigeonpea rows at 40x30 cm spaced 200 cm apart among broadcast millet	0.45	0.70	1.15	0.35	0.63	0.98
Broadcast pigeonpea/millet	0.43	0.61	1.04	0.31	0.53	0.84
Broadcast sole millet	–	1.0	1.0	–	1.0	1.0
Sole pigeonpea at 60x30 cm	1.0	–	1.0	1.0	–	1.0

work financially and paid salaries and wages. The authors' appreciation also goes to J.R. Oteba, Ekuritai, W Akodet, JP Isamat, and B Aryong for their assistance in collecting data.

References

Areke, T.E.E., Omadi, J.R., and Eryenyu, A. 1995. Pigeonpea improvement in Uganda. Pages 79-83 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Areke, T.E.E., Omadi, J.R., Okwang, D.A., and Eryenyu, A. 1996. Pigeonpea breeding at Serere, Uganda. Pages 89-97 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Esele, J.P. 1995. Pigeonpea in Ugandan agriculture. Pages 12-14 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Obuo, J.E. and Okurut-Akol, H. 1995. Effect of spacing on yield of two pigeonpea cultivars in Uganda. Pages 84-86 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Obuo, J.E., Okurut-Akol, H., and Silim, S.N. 1996. Effect of spacing on yield of two pigeonpea cultivars in Uganda. Pages 98-100 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Okurut-Akol, H., Silim, S.N., and Opio, C. 1996. Pigeonpea on-farm research and demonstrations in northern Uganda. Pages 89-97 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 11-12 Oct 1995, Lilongwe, Malawi (Silim, S.N. and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Silim Nahdy M., Musana, M.S., Ugen, M.A., and Areke, T.E.E. 1994. Survey of pigeonpea production and post-harvest systems in three districts in Uganda. Pages 67-73 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 25-27 Oct 1993, Bulawayo, Zimbabwe (Silim, S.N., Tuwafe, S., and Laxman Singh, eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

Ugen, M.A. and Silim, S.N. 1995. Recent research on pigeonpea in Uganda. Pages 87-89 *in* Improvement of Pigeonpea in Eastern and Southern Africa: Annual Research Planning Meeting, 21-23 Sep 1994, Nairobi, Kenya (Silim, S.N., King, S.B., and Tuwafe, S., eds). Patancheru 502 324, Andhra Pradesh, India: ICRISAT

Pigeonpea Research, Technology Exchange, and Seed Production in Malawi

H N Soko[1]

Introduction

Malawi is one of the largest producers of pigeonpea in Africa. Pigeonpea contributes directly to the economic development of the country, in terms of food security and nutrition, nitrogen fixation and nutrient recycling, drought tolerarce, and its adaptability to poor soils. In addition, because of high local demand and good export potential, pigeonpea can generate cash income and thus help alleviate poverty.

Pigeonpea yields in Malawi are still very low, averaging about 450 kg ha^{-1} - less than 25% of the potential yield. However, research efforts during the past decade or so have led to the development of improved technologies including varieties that have been accepted by the market and by farming communities. Efforts are currently geared towards producing more seed of these improved varieties.

The constraints to pigeonpea production in Malawi include:

- Inadequate seed availability of improved varieties
- Inadequate improved varieties with desirable qualities
- Soil- and seedborne diseases (*Fusarium* wilt and *Cercospora* leafspot), insect pests (pod borer *Helicoverpa armigera* and pod-sucking bugs *Clavigralla* spp and *Nezara viridula)*
- Poor soil fertility coupled with poor cultural practices
- Poor market infrastructure
- Inefficient mechanisms for technology transfer.

Pigeonpea Research in Malawi

Organized research on pigeonpea in Malawi started in 1981 with FAO support, and was boosted in 1989 with a collaborative program with ICRISAT. In 1992, the NARS-ICRISAT partnership further expanded with the Eastern and Southern Africa Pigeonpea Improvement Project. The project has developed a range of improved production technologies including improved, adaptable, high yield potential cultivars in all duration groups, along with accompanying production practices.

Most varieties grown by farmers in Malawi are low-yielding, long-duration types that are intercropped with staple food crops. Four key problem areas include: decline in soil fertility, food insecurity, poverty, and lack of crop diversification. Correspondingly, the

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broad NARS research objectives are to develop strategies to:

- Expand pigeonpea production within a short period of time
- Increase adoption rates
- Stimulate export of pigeonpea and pigeonpea products.

The specific research objectives are to:

- Develop varieties with multiple traits (high yield potential, wilt resistance, consumer-preferred seed qualities, adaptability to non-traditional pigeonpea growing environments) in all three maturity groups, tailored to the various cropping environments
- Develop appropriate production technologies including agronomic practices, integrated pest and disease management, and postharvest storage.

Available Technologies

Research in Malawi started with testing the traditional long-duration pigeonpea planted in Nov/Dec and harvested from Aug onwards. From 1986, short- and medium-duration varieties have been selected that can produce fresh pods and dry grain over a longer period than formerly possible. Although short-duration pigeonpea is potentially very high-yielding, it is also especially prone to flower and pod pests, and requires several pesticide sprays to protect yield. Many smallholders cannot afford to spray. In addition, short-duration varieties are not suitable for intercropping with maize because of crop competition.

Pest management research since 1981 has focused on assessing the performance of wilt-resistant varieties. Two long-duration varieties resistant to fusarium wilt disease have been released for production in Malawi. ICP 9145 was released in 1987 and ICEAP 0040 in early 2000. The latter has been identified by the processing industry as having desirable qualities, including a high dehulling percentage (the ratio of the weight of *dhal* to the weight of whole seed before dehulling). Six additional varieties have been developed and are now in on-farm evaluation - two long-duration varieties (ICEAP 00020 and 00053), two medium-duration (Royes and QP 38; <210 days to maturity), and two short-duration varieties (ICPL 87105 and 86012; <150 days).

Crop management practices for pigeonpea in various cropping systems either as an intercrop with maize or in pure stand; double cropping, multiple cropping, winter sowing and ratoon cropping, have been developed with funding from ICRISAT, FAO, and The Rockefeller Foundation. The outputs include: varieties of maize and pigeonpea suitable for intercropping, information on optimal sowing dates, spacing, and spatial arrangements for maize-pigeonpea intercrops, fertilizer requirements, weeding, and harvesting.

Technology Exchange

To accelerate technology exchange, functional linkages have been developed among farmers, researchers, and government/NGO extension staff. On-farm demonstrations have been conducted to promote adoption of legume technologies. A number of collaborators are involved - the Department of Crop Production, Department of Agricultural Research and Technical Services, Department of Agricultural Extension, NGOs such as World Vision

International, Action Aid, and Village Enterprises Zone Association; and several other groups including farmers.

On-farm demonstrations under Action Group 2 of the Maize Productivity Task Force are mounted in all the Agricultural Development Divisions (ADDs) of the country to promote some of the newly released pigeonpea varieties. They have also helped obtain farmers' perceptions of the new technologies and thereby help identify future research priorities.

Other efforts include farmer field training, publication of the Guide to Agricultural Production, promotion through radio broadcasts, and the activities of the Dhal Millers Association of Malawi.

Seed Production Issues

Breeder seed is produced by the breeder concerned, funded by Maize Productivity Task Force Action Group 2. Basic and certified seed is produced by several agencies: Maize Productivity Task Force Action Group 2, National Smallholder Seed Producers Association of Malawi, contract farmers, and the USAID/ICRISAT/ Govt of Malawi groundnut and pigeonpea project.

The Way Forward

Research opportunities and priorities for the future include:

- Variety development for multi-trait genotypes to continue
- Genetic improvement to continue
- Farming systems (soil fertility and plant nutrition) research
- There will be need to expand the capacity of the grain legumes program to select for multiple resistance/tolerance to biotic and abiotic stresses
- Where local expertise is inadequate, technical support will be sought from international agricultural research centers
- The national program will share experiences with other legumes programs in Southern Africa through regional networks
- Collaboration with farmers will continue.

Options for technology exchange will be further explored. These include:

- Use of a collaborative systems approach
- Promoting efficient support services
- Attention to gender roles in agriculture; promoting household utilization of grain legumes will in turn increase production
- Promotion of grain legume technologies through participatory extension methods, improved block extension system, and on-farm demonstrations
- Training of food scientists and technicians
- Strengthening linkages for efficient technology development, modification, dissemination, and adoption by smallholder farmers.

Discussions - Country Experiences and Opportunities

Time-bound research

In many cases, research is conducted with an open-ended time-frame; and sometimes the results of this research lie on the shelf for a further (indefinite) period, unadopted by farmers. This waste of resources would not be permitted, for example, in the private sector. We need to specify a realistic schedule for each research project at the planning stage. Projects that do not come up with concrete results (i.e. technologies ready for dissemination) within this period may have to be closed. This approach will need a change in scientists' attitudes. It may reduce the flexibility of research programs. But it will lead to more efficient, focused research programs and faster development of practical technologies for farmers.

Seed issues

Non-availability of seed is a major constraint to the diffusion of new varieties. For example, ICRISAT's pigeonpea technology exchange specialist spends 80% of his time on seed issues. On-farm trials are encouraging farmer-to-farmer exchange of varieties, e.g. Kat 60/8 in Uganda. However, this diffusion may be associated with loss of genetic purity as a result of outcrossing, as discussed below.

Genetic purity

Farmers can continue to select individual plants of new varieties they grow, and even make improvements in specific traits, as has been observed for pearl millet Okashana in Namibia and sorghum Serena in Sudan. However, this process generally leads to a loss of earliness, because farmer selection for this trait is not always rigorous. Another factor is that the informal system relies on mixtures (farmers plant a mixture of varieties, and informal seed trade is of mixtures), while the commercial market demands specific varieties with specific characteristics. Thus, mixtures and loss of purity due to outcrossing reduce marketability of produce. One solution could be to periodically inject fresh seed of popular varieties into the community.

Regional approach

Pigeonpea is grown over a wide area in the region. But many areas (e.g. parts of Uganda and Tanzania) have similar growing conditions, so variety performance may be similar, and many research results may be broadly applicable. To exploit this, however, we must take a regional approach to pigeonpea research and development. This will involve delineating agro-ecological zones, identifying regional test sites for each major environment, and sharing germplasm more widely.

Phenology and adaptation

Studies on phenology and adaptation represent not only new and important results but also a new approach. Such studies have been conducted on many crops, but generally in a theoretical framework. In contrast, the pigeonpea studies have immediate practical application, identifying specific areas and niches for each maturity group. These studies now need to be taken further, for example by delineating and widely disseminating a list of 6-7 major agro-ecological zones, and varieties suitable for each zone, along with their expected performance.

Plenary Session

Issues for Discussion

Six major issues were identified:

- Increasing awareness
- Systems approach
- Marketing, commercialization, and postharvest issues
- Back-up research
- Funding
- Future priorities.

Increasing awareness

We need to increase awareness about the benefits from pigeonpea, at various levels. Each audience will need information to be packaged and disseminated in a different way.

*7b **farmers*** - cash cropping opportunities and associated quality and market requirements, available varieties and management packages, other benefits such as soil fertility improvement. Easy-to-use information disseminated through flyers in local languages, radio, and television. Extension services and NGOs will play a key role. We should not rely solely on farmer-to-farmer dissemination of information, but aggressively promote available appropriate technologies. One or two experienced researchers in each country could be asked to synthesize available technologies for on-farm promotion.

To the scientific community - commission a series of monographs covering various subjects, e.g. germplasm resources, plant protection, agronomy. These will help consolidate information that is currently available but not easily accessible, being scattered in numerous journals and reports. This will also highlight comparative advantages (e.g. disease hot spots) that can be exploited for regional benefit

Statistical data - data are not easily available on production and yields, except in a few countries such as Uganda. Often pigeonpea statistics are clubbed with other legumes. NARS must build a detailed and accurate database for each country. This will help make a case to policy makers for greater efforts to promote the crop, and also provide a baseline against which to measure future progress.

7b *policy makers* - potential benefits of the crop, demonstrated impact, and economic returns. Specific recommendations on how to promote pigeonpea production and market development, i.e. identifying the key constraints and measures to address them.

7b *donors and visitors to research stations* - documentation of "success stories" e.g. through small illustrated brochures, and impact assessment studies.

Systems approach

Pigeonpea is an important part of traditional farming systems, and farmers are aware that it provides multiple benefits, e.g. food, fuelwood, fodder, and soil fertility benefits. Although it is generally the secondary crop in farming systems, we can capitalize on its widespread acceptance by offering improved varieties that fit into existing fanning systems. This will require a better understanding of each target system, and socio-economics studies to examine cost-effectiveness, farmers' needs and perceptions, community-level structures for seed and grain marketing, and other factors.

Marketing, commercialization, and postharvest Issues

In most crops worldwide, rapid expansion in area and productivity has been driven by market demand and profitability. This is also true of pigeonpea. One major reason is lack of understanding of the market, as a result of which we were unable to target varieties to specific areas with (socio-economic) potential for rapid adoption. Future efforts will therefore focus on commercialization, i.e. encouraging farmers to improve productivity and incomes by adopting new varieties and better crop management, and grow the crop for sale. Successful commercialization will have immediate spillover benefits on the subsistence sector as well.

Back-up research

Essentially, further research should be demand-driven. A preliminary "inventory'' of available technologies will provide a starting point. Gaps in knowledge will thus be identified, where additional research is needed. Simultaneously, as technologies are being disseminated and adopted by farmers, we will receive feedback about problems or shortcomings in these technologies, thus identifying specific areas where back-up research is needed.

We need more information particularly about cropping priorities in different areas, because these will determine the type of varieties - yield and quality are important to farmers producing for sale, while taste and seed size may be more important for subsistence farmers producing for home consumption. Even within a commercial farming system, preferred seed characteristics will depend on end use.

We also need to pinpoint bottlenecks to wider adoption of new technology, using the sub-sector analysis approach described by Freeman et al. elsewhere in these proceedings. This will enable partners to work together to eliminate each bottleneck. It will also identify gaps in knowledge, where additional socio-economics research is needed - for example, causes for wide fluctuations in market demand and exports, ways to reduce transaction costs.

Funding

Both regional and bilateral sources exist, but need to be tapped more effectively. Different donors may be interested in funding different activities; a large pigeonpea R & D program may therefore need to be split into components that can be "sold" to different donors. We also need to improve the efficiency with which we utilize donor funding.

Funding proposals should include specific, measurable targets to allow the donor to monitor progress, e.g. "exports increase to 25,000 tons per year by 2003". The proposal should state clearly how the plan will be implemented, which partners are involved, and what roles each will play.

Funding proposals should be developed for each country highlighting (i) potential high impact at farm level by building on earlier research and donor investments, (ii) partnerships are already in place and functioning well, (iii) several partners, e.g. ICRISAT, CRS, have a regional focus and can exploit spillover benefits. In order to design appropriate intervention strategies, preliminary studies are needed to identify technology packages for promotion and identify the location and size of market niches. Funding should be sought for these preliminary studies.

Future priorities

First of all we need to maximize impact from technologies already available. We must determine which technologies are appropriate for dissemination (see Increasing Awareness to farmers, above), identify partners who will "package" technologies into usable forms, and identify responsibilities for each partner. For example, high-yielding, adapted varieties are available, market potential exists, but these must be tied together with pest control and marketing arrangements and targeted at specific areas or communities.

Recommendations

Our goal is to improve the productivity and sustainability of farming systems, by stimulating wider technology adoption. This is best done by commercialization, i.e. creating opportunities and conditions (including availability of the right varieties) that will encourage farmers to grow a well-managed crop for sale. Commercialization will therefore underpin future efforts to promote pigeonpea technologies in the region. Successful commercialization will create improvements in rural welfare and income. It will also have immediate spillover benefits on the subsistence sector in terms of better nutrition and food security.

Participants made four broad recommendations:

- Contract scientists to write technical monographs on various topics (Variety trials, Germplasm, Phenology and adaptation, etc). These monographs will consolidate information that is currently scattered in journals and reports, providing a comprehensive "inventory'' of the current state of research and identifying gaps in knowledge.
- Identify specific markets, and package available technologies (variety, management) for each of these markets, establish links with marketing agencies where possible. For example, growing white-seeded short-duration vegetable types in Tanzania for sale in Dar es Salaam, growing high-yielding varieties in Uganda for export.
- In order to implement this approach, additional information is needed, particularly on market opportunities. Therefore, approach Rockefeller Foundation or other donors for funding to develop a regional concept note on markets, strategies, and goals for the next 5 years. The concept note will outline the framework for development of individual technology packages. It will also identify comparative advantages and their implications for pigeonpea development targets, e.g. transport costs for exports are high in Uganda, therefore aim for value addition within the country.
- ICRISAT should coordinate these efforts, i.e. development of the concept note and subsequently, individual project proposals. Each participating country should nominate one person to provide data and other assistance in this process. The European Union project should consider expanding into (or funding) market research in its second phase.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on Internationa] Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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ISBN 92-9066-432-0

Order code CPE 130

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