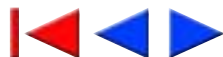


Technology Exchange



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

R B Jones, H A Freeman, and S N Silim¹

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:

- i Dissemination of knowledge, information and research outputs to partners and other stakeholders; and
- ii input and feedback of knowledge, ideas and experiences to ICRISAT from farmers and other stakeholders;
- iii 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 ñ 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:

- ĩ Strengthen national capacities for research and technology exchange
- ĩ Introduce and develop improved genetic material that national programs could further test and release for cultivation
- ĩ Develop and disseminate crop management technologies to improve system productivity and sustainability
- ĩ Strengthen seed production and delivery systems
- ĩ Develop and disseminate technologies to improve processing, utilization, and storage
- ĩ 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 ñ 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?

i Sustainablei 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 farmers 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.

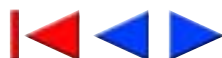
Several cotton companies expressed an interest in working with TechnoServe based on the business plan presented to them, which showed that export of short-duration pigeonpea was a viable business. There were additional benefits including the rotation of cotton with a nitrogen-fixing legume crop that 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.

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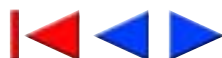


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Farmer Participation in Evaluation of Improved Pigeonpea Varieties in Eastern Kenya

P Audi, R B Jones, and H A Freeman¹

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 erodible soils (Katumani 1995). Under traditional management practices, maize and beans fail in half the seasons, due to 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

- i Determine performance and farmer acceptability of improved pigeonpea production technologies
- ii Disseminate information on improved pigeonpea production technologies to farmers and extension
- iii 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 m² 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 farmers 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 m² 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 ñ one for each of the three duration groups ñ 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 farmers' 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 farmers 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 Chi-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 $p \leq 0.01$

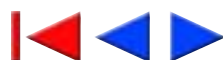


Table 5. Group and individual farmer evaluation of improved pigeonpea varieties in all three duration groups in Kionyweni.

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 ñ especially in the long rains ñ 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.

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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 ñ extension staff, ICRISAT, Kilimo/Sasakawa Global 2000, NGOs, seed producers, farmer associations etc ñ 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 ñ 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:

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

On-farm trials of short-duration pigeonpea

Promising short-duration genotypes were verified over several seasons on farmerís 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 farmers	-	-	ICEAPs 00020, 00040, 00053, 00068, ICPLs 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 <i>chakkis</i>	-	-	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 ñ 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 as 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 in Kiegea village in Kilosa district, Mbweve 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 of trait
	00068	00040	00020	9145	Local	6927	00053	
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 farmers in Dareda/Bacho area, Babati district, 1999.

Trait	Variety performance for each trait				Rank of trait
	00020	00040	00053	Local	
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 maize/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 of trait
	00020	00040	00053	Local	
Early maturity	5	5	5	3	1
Pest resistance	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. However, 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 of trait
	00020	00040	00053	Local	
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 ñ 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 ñ 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 ñ consisting of 200 farmers ñ 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 ñ 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 ñ 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:

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

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Seed Delivery Systems ñ 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.

Source of seed	Local variety		NPP 670	
	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 farmers 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.

Sources	Local pigeonpea		NPP 670	
	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 ñ 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.

Source of information	Learning method (%)	
	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.

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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:

- ï Increases both the scale and the scope of activities
- ï Increases cost effectiveness
- ï Creates a demand for services
- ï Increases accountability
- ï Ensures a pathway from development to promotion and exploitation of research results
- ï 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:

- ï Common goal
- ï Common strategy
- ï Shared commitment
- ï Recognized complementarity
- ï 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 ñ there must be impact on reducing hunger and creating an economic surplus (ICRISAT 1997).

Implicit in a shared goal is concurrence that ìpeople living in extreme povertyî 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.

- ï The expansion of NGO activities in Africa's agricultural development has not been based on solid and impartial evidence of their performance Ö
- ï NGOs have moved far beyond their traditional role as purveyors of disaster relief Ö
- ï 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 Ö

The comment that the traditional role of NGOs is as ìpurveyors of disaster reliefî 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 be 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:

- i Greater use of sub-grants to fund adaptive research activities in an NGO project or fund outreach/extension activities in a research project
- ii Development of joint proposals
- iii 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 ñ 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. Currently 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.



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Discussions ñ 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 ñ ñhiddenî or ñunfeltî 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 ñ rather than accelerate ñ 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 ñ 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.

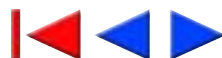
Partnerships and comparative advantages

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 organizationsí 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



partners for a particular activity, ensuring that all partners' skills are used to best effect, and that synergies are maximized.

Adequate consideration must be given to how the partnerships will be implemented. Objectives, plans, and each partner's roles must be spelled out clearly. It is important that wherever possible – and particularly with bilateral partnerships – a Memorandum of Understanding be signed by the highest authority in each partner organization. The aim must be clear delineation of responsibilities, and sustainability of the work after the project closes.



Postharvest Issues



Effect of Genotype, Storage Temperature, Shelling, and Duration of Storage on Quality of Vegetable Pigeonpea

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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 Field 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:

$$\text{Reduced ascorbic acid (mg/100g)} = V * C * 176 / 178,$$

where V = volume of N-bromosuccinimide, C = concentration of N-bromosuccinimide.

Total Titratable 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 ñ ICPLs 93020, 93015, 93064, 93027, and 93047 ñ 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)

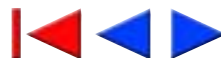
TSS for vegetable pigeonpea differed significantly among genotypes at different storage temperatures whether shelled or unshelled (Table 1). TSS decreased under all storage conditions for all genotypes. Refrigerated peas showed a higher TSS compared to shelf-stored peas. Unshelled refrigerated peas showed 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 ≤ 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, there 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 ($21\pm 3^{\circ}\text{C}$) than in the refrigerator ($4\pm 1^{\circ}\text{C}$) 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.

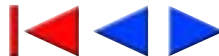
TSS of vegetable pigeonpea decreased in storage. The decrease was more dramatic when the peas were shelled and stored at room temperature. High temperatures accelerate reactions such as breakdown of sugars to release energy (Wills et al. 1981, Kays 1991). Such losses in sugar quantity (and hence lowered 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 and 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 and shelling considerably reduces bulk and therefore storage costs. No wonder then, most grain vegetables the world over, will be stored shelled.

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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°C for 12 h, and then ground using a hammermill.

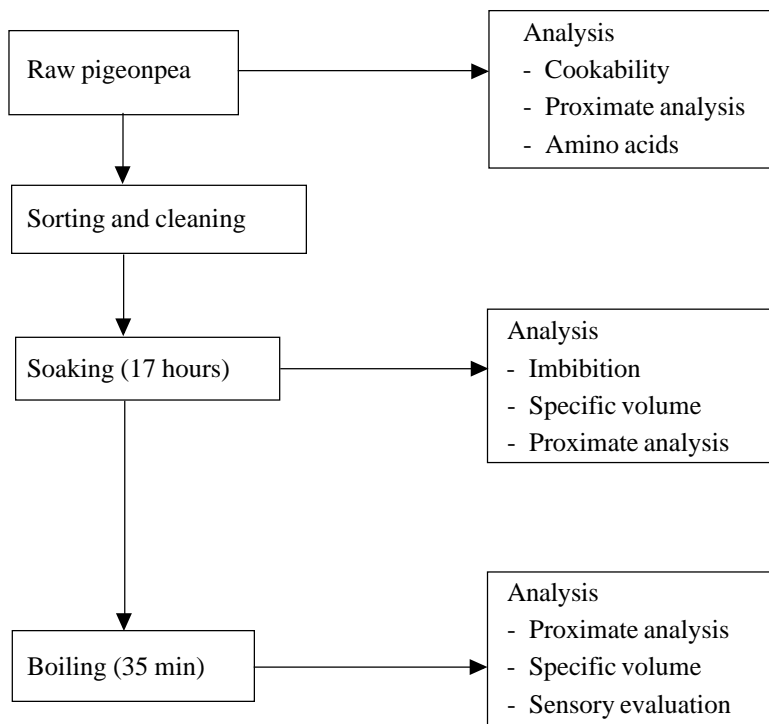
Amino acids in the raw and cooked samples were detected qualitatively using Thin Layer Chromatography.

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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 ($\text{cm}^3/100$ 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 ($\text{cm}^3/100$ 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 composition	ICEAP 00540			ICEAP 00040			Kat 60/8			ICP 6927		
	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	✓	ñ	✓	✓	ñ	✓	✓	ñ	✓
ICEAP 00040	✓	ñ	✓	ñ	ñ	ñ	✓	ñ	✓
Kat 60/8	✓	ñ	✓	✓	ñ	✓	✓	ñ	✓
ICP 6927	✓	ñ	✓	✓	ñ	✓	✓	ñ	✓

Table 3. Amino acid composition of processed pigeonpea cultivars.

Cultivar	Valine	Methionine	Tyrosine	Lysine	Phenyl-alanine	Leucine	Tryptophan	Isoleucine	Threonine
ICEAP 00540	✓	ñ	✓	ñ	ñ	ñ	✓	ñ	✓
ICEAP 00040	✓	ñ	✓	ñ	ñ	ñ	ñ	ñ	✓
Kat 60/8	✓	ñ	ñ	✓	ñ	ñ	✓	ñ	✓
ICP 6927	✓	ñ	ñ	✓	ñ	ñ	✓	ñ	✓



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 volume¹. 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 more 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.



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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.

Treatment	1998a			1998b			1999a		
	Onset	1 month	2 months	Onset	1 month	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

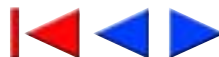


Table 2. Efficacy of different plant leaves on emergence and mortality of *C. chinensis* on pigeonpea stored for 2 months.

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
<i>Lantana camara</i>	114.6 c	44.2 d
Water hyacinth	99.2 c	83.5 abc
Tephrosia	4.0 e	100.0 a
Castor oil	113.6 c	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

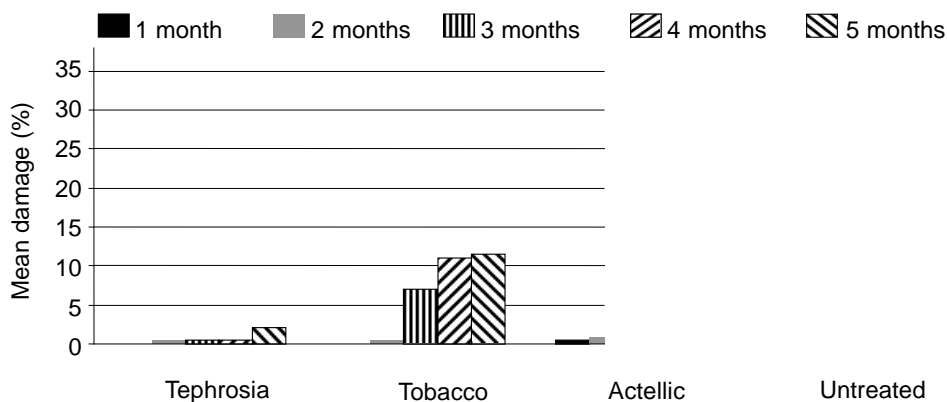


Figure 1. On-farm bruchid damage under different treatments and storage durations, Lira district, 1999 (Agona and Silim-Nahdy 1999).

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/shriveled ñ 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 ñ not seed ñ 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 ñ Tephrosia, tobacco, and solarization ñ 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.

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Discussions ñ 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 grain, 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 Jones¹

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 Gamsler 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.

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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 them 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 ñ from research and extension to farmers and market intermediaries ñ 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:

- i 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.



- i Rural assemblers face high opportunity cost of time collecting small volumes of product from large numbers of producers scattered across rural areas
- i 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.
- i 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 ñ price is based on Fair Average Quality (FAQ), even though final markets distinguish the commodity on the basis of quality differences.
- i 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.
- i 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 farmers and sustainably creating wealth in rural areas we should look more closely at the realities of costs and returns in rural areas.

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Business Principles for Pigeonpea Market Linkage

G Kunde¹

Introduction

In a gathering such as this, among papers such as you have heard, a presentation of this type needs to be 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 distill 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.

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In short, the problem was a dysfunctional linkage between the farmer (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

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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.

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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 Ilonga (506 m) and Naliendele (120 m), 1998/99.

Genotype	Ilonga			Naliendele		
	Days to 50% flower	Days to 75% maturity	Grain yield (t ha ⁻¹)	Days to 50% flower	Days to 75% maturity	Grain yield (t ha ⁻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

Multilocational 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 ratooning ability. 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 the 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 if two 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.

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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 (*dhal*). Pigeonpea is also important in the farming 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 \pm	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
Pigeonpea/beans	0.73	0.48	1.21	0.58	0.53	1.11
Sole beans		1.0	1.0		1.0	1.0
Pigeonpea/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	ñ	797	ñ	874
Sole pigeonpea at 60x30 cm	1362	ñ	1545	ñ
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	ñ	1.0	1.0	ñ	1.0	1.0
Sole pigeonpea at 60x30 cm	1.0	ñ	1.0	1.0	ñ	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.

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Pigeonpea Research, Technology Exchange, and Seed Production in Malawi

H N Soko¹

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 tolerance, 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 ñ 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:

- ï Inadequate seed availability of improved varieties
- ï Inadequate improved varieties with desirable qualities
- ï Soil- and seedborne diseases (*Fusarium* wilt and *Cercospora* leafspot), insect pests (pod borer *Helicoverpa armigera* and pod-sucking bugs *Clavigralla* spp and *Nezara viridula*)
- ï Poor soil fertility coupled with poor cultural practices
- ï Poor market infrastructure
- ï 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:

- ï Expand pigeonpea production within a short period of time
- ï Increase adoption rates
- ï Stimulate export of pigeonpea and pigeonpea products.

The specific research objectives are to:

- ï 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
- ï 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 ñ 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 ñ 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:

- i Variety development for multi-trait genotypes to continue
- i Genetic improvement to continue
- i Farming systems (soil fertility and plant nutrition) research
- i There will be need to expand the capacity of the grain legumes program to select for multiple resistance/tolerance to biotic and abiotic stresses
- i Where local expertise is inadequate, technical support will be sought from international agricultural research centers
- i The national program will share experiences with other legumes programs in Southern Africa through regional networks
- i Collaboration with farmers will continue.

Options for technology exchange will be further explored. These include:

- i Use of a collaborative systems approach
- i Promoting efficient support services
- i Attention to gender roles in agriculture; promoting household utilization of grain legumes will in turn increase production
- i Promotion of grain legume technologies through participatory extension methods, improved block extension system, and on-farm demonstrations
- i Training of food scientists and technicians
- i Strengthening linkages for efficient technology development, modification, dissemination, and adoption by smallholder farmers.



Discussions ñ 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



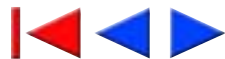
agro-ecological zones, identifying regional test sites for each major environment, and sharing germplasm more widely.

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:

- i Increasing awareness
- i Systems approach
- i Marketing, commercialization, and postharvest issues
- i Back-up research
- i Funding
- i 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.

To farmers ñ 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 ñ 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 ñ 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.

To policy makers ñ 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.

To donors and visitors to research stations ñ 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 farming 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 ñ 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 ñ 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.

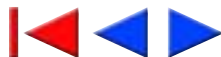


Recommendations

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:

- i 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.
- ii 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.
- iii 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.
- iv 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 International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.





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ISBN 92-9066-432-0

Order code CPE 130

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