Uganda Journal of Agricultural Sciences, 2004, 9:240-249
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ISSN 1026-0919

Experiences with participatory action methods in southern Africa: Can farmers adopt more legumes for productive, sustainable systems?

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Abstract

A case is made here for a renewed focus on legume integration to enhance the productivity base of cropping systems. However, there are significant barriers to farmer adoption of legumes, including limited market access and scarce resources such as seed, labor and land. To develop farmer-relevant technologies it is essential to conduct a cropping system analysis that facilitates systematic involvement of farmers and other partners in developing research priorities and carrying development through to impact. Participatory action research methods, such as the mother and baby trial design, can improve the links in the development chain, enhancing farmer and researcher communication and stakeholder involvement in technology development. We present a case study from southern Africa using participatory action research methods, and the mother and baby trial design to improve maize (*Zea mays*) -based system productivity through legume intensification. Multiple system benefits were obtained due to the fundamental role that legumes play in accessing sparingly-available nutrient pools, which helps improve cropping system productivity and fertiliser efficiency, as well as expanding market opportunities. Yet, historically adoption of legumes has been limited. Farmers grow legumes at a low density and are interested in grain legumes rather than green manure legumes. Intercrops of short season and long season multipurpose legumes, such as soybean (*Glycine max)* or common bean (*Phaseolus vulgaris)* intercropped with pigeonpea (*Cajanus cajan*) can greatly enhance systems sustainability through nitrogen and phosphorus inputs. Using participatory, systems-based analysis we show how farmers and other stakeholders can engage with researchers to explore the desirable traits of legumes currently grown, and where legume use can be intensified. The next steps involve problem solving with farmers, and disseminating legume genotypes that provide dual benefit, from grain and modest but essential contributions to soil fertility. To successfully promote legumes we found that client input needs to be rigorously incorporated early in the process, in addition to addressing market linkages and seed multiplication issues.

Key words: Cropping systems analysis, mother and baby trial design, participatory action research

Introduction

Legumes provide a biologically-sound basis for a nutrient-enriched diet, for the soil and for food security of smallholder farm families. However, the yield potential of staple crops such as cereals and bananas is inherently greater than the yield potential of legumes. Thus high calorie crops tend to be favored over legumes by resource poor farmers. To promote legume integration requires careful attention to farmer priorities and requirements. In this paper we review the basic principles of integration of legumes into cropping systems, and present a case study of participatory research and development experiences working with smallholder farmers in Malawi.

Legume properties

Fundamental properties of legumes underlie the nutritional benefits derived from incorporating legumes into human diets, as well as the long-term sustainabilityof integrating legumes with cereal, tuber or banana-based cropping systems. Legumes improve access to sparingly soluble phosphorus (P) pools and biologically fix nitrogen (N). These are major productivity-limiting nutritional factors in African smallholder cropping systems (Snapp, 1998; Vanlauwe *et al*., 2001). In many Southern and Eastern Africa soils there is sufficient soil P present to support substantially greater productivity, without additional use of inorganic fertilisers, but access to this P pool requires greater legume presence (Snapp, 1999). In particular, legumes that produce large amounts of organic acid root exudates, such as pigeon pea (*Cajanus cajan*) and lupin (*Lupinus luteus*) are able to access sparingly soluble P pools and improve P nutrient cycling efficiency by 30 to 60% (Drinkwater and Snapp, in press; Mapfumo and Maasdorp, 1997). Being effective scavengers of N and P allows legumes to produce nutritionally-enriched vegetation and seeds. However, there are yield penalties associated with the ability to acquire N and P. It requires calories to produce organic acids that access sparingly available P and to support the symbiosis that biologically fixes N; these 'expensive' activities of legumes limit yield potential (Vance *et al.*, 2003). Thus cereals are intrinsically able to produce much larger quantities of calories than legumes, but cereals are reliant on external inputs of N and P, or the presence of legumes to increase N and P availability. Calorie-short farmers have understandably prioritized cereals. This traps farmers in a declining productivity system, as cereal monocultures without sufficient fertiliser inputs will decrease in yield potential over time. Productivity can be maintained only if large amounts of soluble N and P are applied, or legumes are adopted, or an integrated approach is followed that combines legumes and judicious use of small doses of fertiliser (Bationo and Ntare, 2000).

A fundamental property of reliance on soluble fertilizer to boost cereal productivity is inefficient utilization. World-wide estimates of P-fertiliser efficiency are about 20% (Vance *et al.*, 2003), and N-fertiliser efficiency ranges from 30 to 60% (Cassman *et al.*, 2002). Smallholder farmers urgently require cropping systems that maintain calories while efficiently using nutrients from organic and inorganic sources. Legume intensified systems can help retain and access nutrients from biological pools, thus improving nutrient cycling efficiency and system productivity. If sufficient legume biomass is produced, it may also be possible to enhance soil organic matter, but this has proved difficult to realize under the variable and degraded soil environment of many smallholder fields (Kanyama-Phiri *et al.*, 1998). Another challenge is that farmers remove seed and leaf products from legumes which will necessarily reduce the N and P inputs from incorporating legumes in a cropping system.

A nutrient budget conducted along a transect of farms in a southern Malawi watershed has shown that adoption of pigeon pea can reverse a relentless erosion of soil N and P to instead, a slow accumulation of N and P fertility (Snapp, 1998). On an annual basis, the net P inputs in a maize-based cropping system with no pigeon pea presence were found to be -6.2 to 3.4 kg P per ha. In contrast, farmers who had adopted intensified use of a maize-pigeon pea intercrop had net P inputs in the range of 1.2 to 11.3 kg P per ha (Snapp, 1998). Biological nitrogen fixation, the transfer of P from unavailable to available organic-P pools, and reduction in erosion through enhanced leaf cover were observed to contribute to net P and N gains from incorporating pigeon pea into the maize-based cropping system. There are contrasting views literature about the extent that legumes enhance N and P availability in the short-term, as a sizeable portion of legume residue-N and -P will build organic soil pools and not be immediately available to subsequent crops (Sanginga *et al.*, 2003). Yet there is growing evidence that a substantial enhancement of biologically-available N and P is possible from intensifying legume presence within resource-poor cropping systems (Table 1).

Challenges to legume adoption

Despite the clear nutritional benefits associated with growing more legumes, the barriers to legume intensification are sizeable and should not be underestimated. This is indicated by the limited adoption of legumes in current smallholder cropping systems (Sanginga *et al.*, 2003). As shown in Table 1, adoption of intensified legume systems has been low in many regions of sub-Saharan Africa, despite large promotion and research efforts. It is important to note that legume presence is wide-spread among smallholder farmers, but it is generally at very low levels. The presence of small amounts of grain, vegetable and fodder legumes within current cropping systems should be viewed as important opportunities.

In this paper we present experiences in Malawi with participatory action research conducted with farmers to explore opportunities to enhance legume presence, and to investigate the consequences for productivity of the maize-based cropping system. This case study draws upon earlier experiences with an on-farm participatory approach called the mother and baby trial design, which seeks to rigorously incorporate farmer evaluation as legume options are tested (Snapp, 2000). A key feature in this participatory research process is that assessment is built in each year. Thus, legume performance in cereal-based systems is evaluated by the full range of stakeholders, and a range of 'best bet' options selected for wider evaluation and dissemination.

(Snapp *et al.*, 2002a). A key lesson learned from our preliminary research was that legume intensification of cereal systems will not occur unless farmer requirements for calories and cash are addressed first (Snapp *et al.*, 2002b). This requires that market-linked and whole system approaches be used to select and promote appropriate legumes.

Building on a participatory plant breeding model (Sperling *et al.*, 2001), we discuss here how a wide range of multi-function legume genotypes can be tested, to identify those that fit into different niches of cereal systems. The foundation of this approach is to use participatory research approaches with built in 'feedback loops' to systematically involve farmers and other stakeholders in every step of legume selection and dissemination. A recent farmer survey conducted in Nigeria indicated that adoption of new varieties has been consistently over 40%, compared to adoption of leguminous cover crops at about 18% (Morse and McNamara, 2003). This is due to many factors, including those discussed below, but we also contend that participatory breeding has led to improved adoption of crop varieties, and that a similar participatory research approach can enhance adoption of legume species.

Table 1. Legume intensified technologies such as intercrops or fallow systems and the residue nitrogen or phosphorus contributed to build soil fertility and cropping system productivity. Farmer adoption status is presented if available.

Region	Technology	Residue Nitrogen	Residue Phosphorus	Farmer adoption	References
		kg ha-1	kg ha-1		
Benin and Malawi	Mucuna for weed control and soil improvement	20 - 208	Not determined	Initially high – farmers sold seed to NGOs and used mucuna to control weeds. Over the longer term, however, there has been minimal adoption	Schulz et al., 2003 Versteeg et al., 1998 Snapp and Silim, 2000
Malawi	Tephrosia intercrop or fallow for soil fertility	15 - 96	Not determined	Adoption by ~25,000 households receiving incentives from Malawi Land Resource Center project	Snapp and Silim, 2000 Bunderson, 2003
Southern and Eastern Africa	Pigeon pea intercrops in maize based systems	20 - 120	2.2 - 13	Adoption level closely related to market opportunities for pigeonpea	Jones et al., 2002 McColl, 1989
Kenya	Lablab/pigeon pea intercrop	75	7.3	Nil adoption	Simpson, et al., 1990
Malawi	Groundnut/pigeon pea intercrop, Rotated with maize	23 - 105	2.1 - 5.5	Adoption level closely related to market opportunities for pigeonpea and groundnut	Snapp et al., 1998 Kanyama-Phiri et al., 2000
West Africa	Promiscuous soyabean for grain and soil fertility	38 - 126	Not determined	Adoption high where soyabean markets are present (new products and feed)	Sanginga, 2003
Malawi	Sesbania/maize intercrop	28-63	2.5-5.7	Nil adoption	Kanyama-Phiri et al., 1998 Phiri et al., 1999
Zimbabwe	Lupin green manure	18-47	2.0-5.2	Nil adoption	Mapfumo and Massdorp, 1997

There are unique challenges associated with legumes that act as barriers to adoption. These include the following biological factors: 1) the moderate yield of legumes compared to cereals and tubers, which is directly related to the nutritious protein and oil content of legume seeds that are 'biologically expensive' to produce, thus limiting yield potential; 2) legume reliance on the biologically expensive biochemical processes of biological N fixation and phosphorus mineralization (which supports legume growth on infertile soils); and 3) relatively few, large seeds are produced per plant. This last means that the legume multiplication ratio is low, necessitating time and resources be invested to build supplies of improved seed and to disseminate seed. Further, this tends to enhance the cost of seed. This cost combined, with relatively low yield potential and high labor requirement (associated with harvesting and weed suppression in some legumes), leads to the necessity that farmers obtain high returns from legumes.

As well as biological factors, there are socio-economic factors that act as barriers to farmer uptake of legumes (Snapp *et al.*, 2002b). These include: 1) limited and uncertain market access for legumes; 2) unstable and highly variable prices for legumes across locations and time; 3) insufficient farmer access to improved legume germplasm with desired quality traits, and with a range of growth and maturity habits to fit into different market and cropping system niches; and 4) limited attention by researchers to selecting and disseminating legumes with superior ecosystem service properties, such as enhancing available nutrient pools, reducing pests and improving system productivity.

Participatory research to develop legume-based technologies

The importance of cereals and bananas to calorie-insufficient farmers is the environment within which relevant legume research must be conducted. Farmer goals for incorporating legumes in a given cropping system need to be evaluated and addressed as the starting point for legume-intensification research. Different market and cropping system niches should be identified and a wide range of legume options developed for both market-oriented and subsistent production (Snapp *et al.*, 2003). All the links in a seed-to-market chain require attention, in order for legume adoption to be successful (Jones *et al.*, 2002). The impact of a legume on soil fertility, pests and whole system productivity needs to be simultaneously considered. As discussed in a paper by Pound et al., this conference, it is critical that farmers are involved from the beginning of the process to identify research priorities and relevant, potentially adoptable technical solutions. Pound and colleagues describe a participatory research and extension process that insect pests of groundnut and pigeon pea as a top priority in one region of Uganda. Through this type of participatory, whole systems analysis it is possible to identify and address the bottlenecks and problems that farmers face.

We propose here that a legume promotion or intensification program be designed around the characteristics of a successful participatory plant breeding program. Participatory plant breeding has been shown to be an effective means to develop and disseminate cultivars adapted to low yield environments, and to enhance adoption among smallholder clients who have not been served by conventional breeding programs (Atlin *et al.*, 2001). Rather than focusing on improving a single species, a participatory selection process should focus on improving legume options that fit within current cropping systems. The initial sites for working with local communities require careful consideration, so that they are representative of cropping systems over a region or zone where dissemination is planned. The next steps are to characterize and document desirable properties of legume genotypes, by researchers and stakeholders working together. In our case study described below this involved initially a literature review and a baseline survey conducted in the villages selected for participatory research trials (Snapp, 2002). In participatory breeding efforts this initial characterization step has also involved focus groups, expert farmer panels, and participatory on-farm trials (Johnson *et al.*, 2000; Sperling *et al.*, 2001).

Careful attention is required to every link in the seed-production-use chain. On the supply side, the large seed size of legumes means that ensuring wide-spread seed availability is a critical link that must be proactively addressed from the beginning of the project (David and Sperling, 1999). On the demand side, access to markets is a challenge as well and market development must be a priority, through interdisciplinary research collaborations involving agricultural economists, NGOs and private enterprise representatives (Snapp *et al.*, 2003). Examples of a market-chain link approach to development of improved genotypes and market share for smallholders is illustrated by recent experiences in southern Africa with pigeon pea (Jones *et al.*, 2002). If a variety has clear market advantages it will to some extent 'sell itself' over time (David and Sperling, 1999).

Multiple benefits must be simultaneously assessed, to identify both immediate, marketable assets and longer-term contributions from 'ecosystem services' traits. Tradeoffs often occur between legume traits that enhance marketable yield, or reduce labor requirements, and legume traits that maximize ecosystem benefits. In general, legumes with indeterminate growth habit that produce large amounts of forage or leaves for vegetable use (but limited amounts of grain) tend to have the greatest soil building properties, but may require greater investments in labor to harvest multiple times (Snapp and Silim, 2002). The specifics of tradeoffs differ with each cultivar, and research is urgently needed to identify genotypes that optimize a combination of benefits (Schulz *et al.*, 2003).

Malawi case study

Case study - materials and methods

A study was conducted over the 1998-2000 growing seasons in Chisepo, Central Malawi to assess the potential of legumes to intensify maize-based cropping systems. This participatory research drew upon lessons from a project reported on previously (Kanyama-Phiri *et al.*, 2000; Snapp *et al.*, 2002a). The mother and baby trial design was used to conduct on-farm research with 32 farmers. The mother and baby trial design is described by Snapp (2000; 2002). It is a method to methodically link 'replicated within a site' researcher-led mother trials with 'one site, one replica' farmer-led trials. The 'within site replicated' mother trials are conducted at central locations (on research stations, near schools or community centers) and compare a large number of technologies, such as different varieties grown at low and high fertility levels. On-farm baby trials are conducted simultaneously with the mother trial, to compare a sub-set of the technologies, frequently those chosen by the farmer implementing the baby trial (Snapp *et al.*, 2002a). In addition to rigorously incorporating farmer evaluation and involvement in management of legume-intensified systems, the mother and baby trial approach involved systematic meeting with communities to discuss findings each year, and decided through a partnership what further research should be conducted.

In 1998 village meetings and visits to neighboring research centers were initiated with interested farmers to discuss potential soil fertility enhancing technologies. A farmer survey in an adjacent village had previously shown that less than one-third of farmers in the region used inorganic fertilizer regularly, and only 10% of farmers applied more than 50 kg N fertilizer to maize (Snapp *et al.*, 2000b). Farmers in the area appear to be well aware of soil fertility problems, and interested in using fertilizers, but the majority surveyed found inorganic fertilizers consistently unprofitable or unaffordable. Thus it was not surprising that we found strong interest among farmers in testing legume-based technologies to improve soil fertility.

Dual purpose and green manure legumes were chosen by farmers as promising options to evaluate and a 'mother trial' with three replicates was established near the village headman's farm, in the center of the village (Table 2). Thirty-two 'baby' trials were established by farmers in collaboration with researchers to further evaluate legume options. Twenty-seven of the baby trials were successfully carried out and monitored by researchers over the project period, although more recently it was observed in a nearby village that farmers who carried out baby trials or were exposed them have begun to experiment on their own and more than 50 on-farm experiments are underway, similar in design to baby trials (although more informal in layout) (N. Johnson, unpublished data).

Table 2. Legume-maize cropping system technologies compared on-farm at Chisepo, Malawi over two years

Treatment	Year 1 (1998/99)	Year 2 (1999/2000)
1	Maize, No fertilizer	Maize, No fertiliser
2	Maize + 35 kg Nha^{-1}	Maize + 35 kg Nha^{-1}
3	Pigeon pea/G. nut intercrop	Maize, no fertiliser
4	Maize /Tephrosia intercrop	Maize/Tephrosia intercrop
5	Mucuna/maize rotation	Maize, no fertiliser
6	Maize /Pigeon pea intercrop	Maize/Pigeon pea intercrop

The legume species chosen for testing were 'best bet' multipurpose legume species that fit farmer and market requirements. They were identified through a joint process involving researchers, farmers and other interested stakeholders (e.g., consumers, buyers and processors). The goal was not to identify the best legume for soil fertility, but instead to select a range of legumes that fit different niches in cereal-based systems, including subsistence use to enhance farmer nutrition, expansion of cash cropping opportunities and soil-productivity building properties. Early, short duration legumes that can be rotated with cereals as well as long-duration legumes that can be relay or directly intercropped with cereals. Thus, different temporal and spatial niches were addressed to expand legume options for farmer use, addressing both market and home-use opportunities.

The legumes tested were mucuna (*Mucuna pruriens*), pigeon pea, Fish plant (*Tephrosia volgelii*), and groundnut (*Arachis hypogea*), see Table 3 for a full description of population density and cropping systems compared. Mucuna was grown in rotation with maize, pigeon pea and groundnut (*Arachis hypogea*) were intercropped in the first season and followed by maize. Pigeon pea and tephrosia were continuously intercropped with maize. In the second year, the response of maize to residual nitrogen (N) from legumes was observed by evaluating maize yields and conducting a comparison of legume-intensified maize to sole maize, grown with and without 35 kg N per ha inorganic fertiliser. This check system is representative of smallholder maize production in Malawi.

The choice of 'multipurpose' legumes tested in this research was initially somewhat controversial among researchers and extension participants who were primarily interested in testing agro-forestry systems such as leguminous-maize alley cropping and improved fallows that have substantial soil building and pest-suppressing properties (Kanyama-Phiri *et al*, 1998). By contrast, multi-purpose annual legumes that are harvested for grain – and thus nutrients in the grain are removed - have necessarily limited potential to build soil. At the same time there was concern that farmers, some of whom were at the edge of survival, might be best served by legumes with short as well as long-term benefits. Discussions with farmers led to a full range of legumes being chosen for testing that represented a range of soil fertility inputs, from high (the agro-forestry shrub *Tephrosia volgelii)* to low (groundnut).

Case study - results and discussion

The performance of the legumes under farmers' conditions was encouraging. Yields of maize in rotation or intercropped with legumes were higher than sole maize grown without fertilisers (Table 4). This check system of sole cropped, unfertilised maize is representative of smallholder maize production in Malawi as maize is grown continuously with very small doses or no fertilizers throughout the vast majority of the country (Snapp *et al*., 2002b). Maize grown in rotation with mucuna produced the highest yield, over 240% higher than the continuous maize check system (Table 4). This treatment, maize after mucuna, was slightly higher yielding (10%) than maize fertilised with 35 kg N ha^{-1} (Table 4). However, for farmers that are short on land, maize grain yield produced should be considered over two years. This is in many cases a more appropriate time-frame to farmers who have scare resources and can't invest land in green manure crops without an adequate return. Over two years, unfertilsed maize and maize grown after a mucuna rotation had comparable yields, about 2.2 tonnes grain ha^{-1} 2 years^{-1} (Table 4). This is insufficient to support a family of 5. The net economic benefits estimated in Table 4 also indicate that unfertilised maize and maize grown after a mucuna rotation are not high performing options.

Taking into account a two year time frame, the grain yield of fertilized maize was the best performing option at ~ 4.0 tonnes grain ha^{-1} 2 years^{-1}, double most other options (Table 4). However, there are high costs associated with using fertiliser in a country with a relatively high price ratio of fertiliser-to-maize grain (Benson, 1997). Indeed, if an average fertiliser price is used of US$ 0.20 kg^{-1}, then net benefits are highest with the maize+pigeonpea intercrop system,

Table 3. Legume-maize cropping system technologies description in terms of biological and farmer considerations

Technology	Population density (X1000)	Biological characteristics	Farmer perceptions of characteristics
1. Maize control	Maize: 37	Maize hybrid MH18, three maize plants per planting stations, 0.9m X 0.9 m.	Current farmer practice throughout Malawi.
2. Maize + fertilizer	Maize: 37	Maize hybrid MH18, three seeds per station	Use little fertiliser (17 kgha^{-1}) as it is costly, gives high yields
3. Maize + pigeonpea (PP) intercrop	Maize: 37 PP: 37	Temporal compatibility. PP variety ICP 9145 planted at the same time as maize, 3 plants per planting station spaced halfway between each maize station. PP grows slowly, which reduces competition with maize.	PP is a bonus crop; low density system minimizes impact on maize yields.
4.Mucuna rotation	74	Local variety, poisonous if not properly cooked	Difficult to intercrop at a high density, Good cover of soil hence control weed, Not heavily attacked by pests
5. G'nut + PP intercrop year 1, rotation with maize year 2	G'nut: 74 PP: 37	Groundnut variety JL 24 or CG 7 was grown as a single row on ridges spaced at 0.9 m spacing. To enhance residue biomass quantity and quality, a 'bonus' PP crop is intercropped with the short duration grain legume.	Legume seed density takes into account expense of groundnut seed and farmer-adoptable seeding rates. Ppea is a bonus crop.
6. Maize + Tephrosia relay intercrop	Tephrosia: 20 kg/ha Maize: 37	Temporal compatibility enhanced by planting Tephrosia at 1st weeding. Tephrosia has an initially slow growth habit. Green manure screening studies have shown the widespread adaptability of Tephrosia to Malawi	For a green manure system to be adopted by farmers, it must minimize labour required. Seed is broadcast along ridge and

followed by maize + fertilizer and the pigeonpea+groundnut intercrop rotated with maize (Table 4). Legume grain prices relative to maize grain prices vary substantially from the 2:1 ratio assumed for the economic comparison, to as high as 5:1 as low as 1.4:1 (Phiri, 1999). Clearly, if groundnut or pigeon pea prices are relatively high, then the benefits from these intercrop systems will be enhanced relative to sole maize systems.

The farmers who conducted baby trials evaluated performance of legume options according to three different traits, perceived labor requirements, soil fertility enhancement properties and overall value (Fig. 1). The mucuna-maize rotation was generally ranked best for improving soil fertility and the groundnut+pigeon pea system came second. However, when it came to reducing labor requirements and overall perceived value, women farmers preferred the pigeon pea-based systems. It was interesting that male farmers did not rank the overall value of the maize+pigeon pea intercrop very high at 2.2, whereas female farmers ranked the same system much higher at 3.6 (Fig. 1). This may be related to a degree of weed suppression associated with this system (see for example Snapp and Silim, 2002) and the value women find in systems that reduce weeding-labor, which is primarily a women's responsibility. In addition, women farmers tend to use pigeon pea products for home consumption in this area (primarily the green vegetable pods), whereas men farmers are more likely to be responsible for selling groundnut and maize produced, and thus be interested in systems that increase returns from these crops.

Table 4. Grain yield and economic benefit of legume-maize cropping system technologies evaluated on-farm at Chisepo, Malawi. Overall grain yield combines maize and legume yield over two years

	Maize yield 2nd year kg ha^{-1}	Legume yield (P'pea+g'nut)	Grain yield overall	Economic benefit US$ ha^{-1} 2 years^{-1}	Costs that vary	Net Benefits
Maize	1003^{a}		1950^{a}	253.5	0	253.5
Maize + 35 kg N ha^{-1}	2206^{c}		3986^{c}	518.2	62	456.2
Pigeonpea+G.nut intercrop/maize rotation	1788^{b}	301+419	2517^{a,b}	419.6	22	397.6
Maize+Tephrosia intercrop	1599^{b}		2742^{b}	356.5	11	345.5
Mucuna/Maize rotation	2461^{c}		2461^{a}	319.9	11	308.9
Maize+Pigeonpea intercrop	1752^{b}	328+211	3241^{c}	491.4	11	480.4

Economic benefits were calculated using average prices for maize (US$ 0.13 kg^{-1}) and grain legume (~2-fold higher at $US 0.26 kg^{-1}), and costs that vary across technologies, including 35 kg N ha^{-1} fertiliser at the farm gate (US$ 30.00 ha^{-1}), estimated labor for fertiliser or extra seed application (US$ 1.00 ha^{-1}), and seed of legume cultivars at (US$ 10.00 ha^{-1}). Sources of prices and costs were Snapp *et al.* (1998).

Participatory research meetings with farmers also highlighted other problems and opportunities with these different legume options. For example, farmers pointed out that it would be difficult to practice the mucuna rotation where land shortage is a problem (Kamanga, unpublished). Seed availability is an on-going problem, as is market access for new varieties of groundnuts and pigeon pea introduced through this project that have yet to gain wide acceptance in market channels. We did pay attention to market prospects, and processors of groundnut and pigeon pea were involved in the selection of the improved varieties used in this project. However, we did not include initially any representatives among intermediate market buyers such as local government depots and traders. Some reluctance was initially encountered among intermediate purchasers to try the new grain type from the improved varieties of groundnut and pigeon pea. After a two-year period, there has been substantial adoption of intensified groundnut and pigeon pea systems, intercropped and rotated with maize (Kamanga, unpublished). Other legumes have not been adopted to any significant level. Continuing barriers to wider adoption beyond the initial village involved in the project include limited seed availability and animal control problems (animals feeding on long-duration legumes before they can be harvested, as traditionally animal control is limited to the maize growing season, and the legumes grown in these new systems are still in the field after maize harvest). Labour shortages are also periodically noted by farmers as limiting legume adoption, particularly for the maize+tephrosia intercrop system which requires a difficult operation using hand hoes, the incorporation of relatively woody biomass. Other research in the region has found similar findings to this project in terms of seed access (Snapp *et al.*, 2002b; Tripp and Rohrbach, 2001). A significant barrier to legume use by smallholder farmers is a lack of access to improved seed and generally limited legume seed availability during the planting period.

We found that developing appropriate seed multiplication and dissemination strategies is critical for successful legume adoption. There are however significant challenges to improving seed availability of self-pollinated species with limited seed multiplication ratios, and primarily subsistence use – that have limited potential for promotion through private enterprise seed industries (Tripp and Rohrbach, 2001). Recommendations on means to improve legume seed availability include the strengthening of farmer capacity to be effective evaluators and users of improved seeds, along with development of local and larger-scale commercial seed enterprises, linked to development of new market opportunities for legume products (Jones *et al.*, 2002).

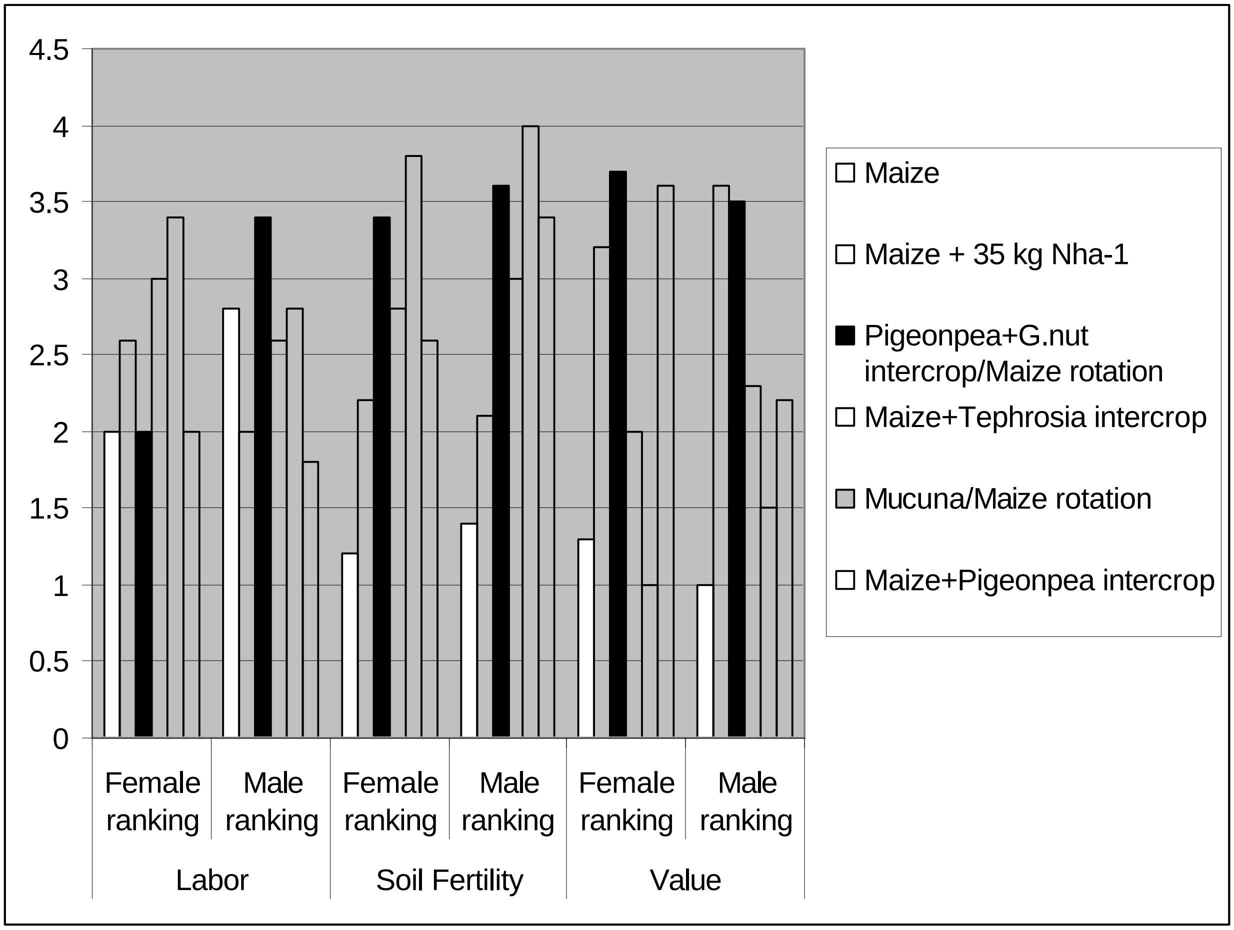

Fig. 1. Ranking by farmer participants in baby trials to evaluate legume-maize cropping system technologie Chisepo, Malawi, from 1998-2000. Female farmers and male farmers evaluated technologies separately. The ran was on a scale of 0 to 4 for three traits, where 0 = low labor requirement or low soil fertility or low value and 4 = labor requirement, high soil fertility enhancement and high value.

Conclusions

Promising multi-use legumes for smallholder farmers in southern and eastern Africa are long-duration varieties of pigeon pea, cowpea, *Mucuna,* climbing beans and soybean. These have the greatest potential to enhance soil N and P status, while at the same time providing immediate term grain and vegetable products to enhance food security or market opportunities. Legumes that are candidates for adoption should be evaluated within local cropping systems (e.g., maize and banana) where performance criteria and ranking traits are chosen by farmers and researchers working together. These might include quality traits of seed and vegetation or fodder, productivity of the whole legume-cereal system, and a biological contribution assessment (e.g., residue N and P).

Initially a wide variety of contrasting plant types and yield potential should be included among introduced legumes, so that both early and late duration varieties and a range of seed quality types can be evaluated in terms of integration and performance within local cropping systems and market niches. As the participatory research process develops, the evaluation process provides feedback to researchers regarding which types of legumes are valued, for which niches within the cropping systems. As options are identified and niches documented, this will enable researchers and extension advisors to introduce specific varieties with locally valued characteristics. An important lesson from our research is that there are tradeoffs between soil enhancing properties and farmer-acceptable traits. In our case, although the most promising soil fertility enhancing legumes were tephrosia and mucuna, the only farmer-acceptable legumes were groundnut and pigeon pea, which had potential for market sales and home consumption.

Overall our experiences illustrate that it is important to ‘build in’ a voice for farmers and other stakeholders in the research process. This can be through joint discussions of outputs, investing time and resources in forging farmer-researcher partnerships and through conducting surveys. Farmers provide unique insights into analysis and results.

Identification of trade-offs and reasons for variation in performance can be the basis for new hypotheses. The whole systems approach explored here takes participatory research a further step, through integrating research on sustainability of technologies with the participatory process, to understand farmer criteria, and enhance adoption.

Overall this paper presents evidence from literature review and on-farm research experience in Malawi that makes a case that smallholder farmers prefer dual purpose legumes that provide cash and nutritional value, as well as longer-term soil building contributions. Legumes such as green manures with exclusively soil enhancement properties are not economical or practical for farmers to adopt under most circumstances. Dual or multipurpose legumes do not provide rapid or immediate soil amelioration and are rather a component of long-term sustainable soil management. In sum, the selection of legumes appropriate to smallholder farmer resources and priorities requires a whole systems approach that pays attention to market development and seed sources, as well as legume production issues.

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