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Farmer Experimentation to Assess the Potential of Legumes in Maize-Based Cropping Systems in Malawi

Bernard C.G. Kamanga
Risk Management Project, Natural Resources Group
CIMMYT-Malawi, Bunda College of Agriculture, Lilongwe, Malawi

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Abstract: The AusAID/ACIAR/CIMMYT Risk Management Project develops resource-conserving farming methods in collaboration with smallholder farmers, combining use of crop simulation modeling and farmer participatory research (FPR). On-farm trials involving 32 farmers were conducted to assess the potential of legumes (mucuna, pigeon pea, tephrosia, and groundnuts) in maize-based cropping systems in Chisepo, central Malawi, 1998-2000. Five treatments were tested: mucuna grown in rotation with maize; pigeon pea and groundnuts intercropped in the first season and followed by maize in the second; pigeon pea continuously intercropped with maize; and tephrosia also continuously intercropped with maize. The response of maize to residual nitrogen from the legumes was observed in all treatments The maize-mucuna rotation produced the highest increase (over 100%) in maize yields, but would be difficult to practice where land is short.The mucuna-maize rotation was the most beneficial for improving soil fertility, followed by the groundnut/pigeon pea intercrop. Female farmers preferred pigeon pea systems for the food security they offer. Two years after the study, groundnuts and pigeon pea have been integrated into farming systems by farmers other than the original 22 participants. Seed availability, damage by animals, and labor shortages have constrained total adoption.

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Summary

A study was conducted to assess the potential of legumes in maize-based cropping systems in Chisepo, central Malawi, 1998-2000. The mother-baby trial approach was used to set up on-farm legume trials with 32 farmers. The legumes used were velvet beans or mucuna (*Mucuna pruriens*), pigeon pea (*Cajanus cajan*), fish plants (*Tephrosia vogelii*), and groundnuts (*Arachis hypogea*). Five treatments were tested: mucuna grown in rotation with maize; pigeon pea and groundnuts intercropped in the first season and followed by maize in the second; pigeon pea continuously intercropped with maize; and tephrosia also continuously intercropped with maize. The response of maize to residual nitrogen from the legumes was observed in all treatments and these maize yields were compared to those of monocropped maize grown without fertilizer (the control). The performance of legumes under farmers' conditions was encouraging. Yields of maize in rotation or intercropped with legumes were higher than the yield of the maize control. The maize-mucuna rotation produced the highest increase (over 100%) in maize yields, followed by the groundnut/pigeon pea intercrop. The mucuna-maize rotation was the most beneficial for improving soil fertility, followed by the groundnut/pigeon pea intercrop. In terms of food security, however, female farmers, in particular, preferred the pigeon pea systems. In addition, farmers pointed out that although the mucuna rotation was best, it would be difficult to practice where land shortage is a problem. Two years after the implementation of this study, groundnuts and pigeon pea have been integrated into farming systems by farmers other than the original 32 participants. Seed availability, damage by animals, and labor shortages have been some of the barriers to total adoption of legumes.

Introduction

Maize is the dominant cereal and food crop in smallholder agriculture in Malawi. In most parts of southern Malawi, maize is intercropped with pigeon pea, cassava, beans, pumpkins, and mucuna (ICRISAT/MAI 2000; Snapp et al. 1998). Groundnuts are usually grown in a two-year rotation with maize, and farmers also find it suitable for intercropping with maize (Chiyembekeza et al. 1998). Most farmers intercrop to maximize land use and diversify their food consumption (DARTS 1998; Shaxson and Tauer 1992). In the process, more and more farmers are realizing that some or all legumes have residual benefits for maize production (Benson 1998; Sakala 1999).

Maize has a high yield potential and is suited to a wide range of climates. Labor demands for maize production and processing are relatively lower than for other crops (Leach 1995). However, maize productivity is declining due to diminishing soil fertility, resulting mainly from over-use by the region's increasing population. The net result is a reduction in the food security of subsistence farmers. Diagnostic studies in Malawi have indicated that farmers themselves are aware of this problem (Diagne 1998; Kamanga 1999). The main task is to determine how to combine farmers' knowledge of legumes with technical expertise to make the crop not only sustainable but also economically viable and environmentally sound (Reeves 2000).

Maintaining soil fertility in Malawi requires approaches that encourage the efficient use of all available nutrient sources in smallholder soil management. McCalla (2000) pointed out the need to create a set of technologies, incentives, and policies that encourage smallholder farmers to use their resources in a sustainable manner. Including legumes in smallholder systems is a step in the right direction.

Research by scientists at the Department of Agricultural Research and Technical Services (DARTS) and the University of Malawi has explored a wide range of options for biological and mineral management of soil fertility (Coote et al. 1998). Of these, best-bet legume technologies coupled with good land husbandry methods are likely to have significant benefits for food production. Various combinations of organic and inorganic fertilizers for crop production look promising. Many studies have reported encouraging results from work on the effects of combinations of organic and inorganic fertilizers on maize yields (Kumwenda et al. 1995; Snapp 1995; Myers et al. 1997; Kamanga 1999; Jones et al. 1997; ICRISAT 2000). This means that resource-poor farmers who cannot afford adequate fertilizers could benefit greatly from the inclusion of legumes in maize-based systems under appropriate management. However, adoption of such options by smallholder farmers is low (Gueye 1999; Becker 1990). Adoption levels may increase if farmers are given better options. More importantly, though, farmers need to be fully involved in the technology development process to give them a sense of ownership of the technologies and, hence, increase adoption (Veldhuizen 1997; Anandajayasekeram 1996; Tan 1986). Meaningful participation by farmers occurs when their current activities form the foundation of the technology development process, so that their knowledge is continuously incorporated (Bellon 1998; Gueye 1999).

Veldhuizen et al. (1997) defined farmer experimentation as the capacity of farmers to change their farming situation through innovative thinking and experimentation. This refers to experiments that farmers define and control themselves, making their own observations and analyses. Farmers decide what to test based on what they see or hear from other farmers and from observations made within their biophysical and socioeconomic environments. This type of experimentation is raises farmer confidence in the relevance of the work and increases the likelihood of farmer participation in technology development (Orr et al. 2000). Farmer experimentation also provides an opportunity to analyze farmers' practices, perceptions, and circumstances.

In this study, legume-based trials were identified and given to farmers to manage under their conditions. This procedure deviated slightly from the definition of farmer experimentation given above, because most of the test legumes were new to the farmers, who therefore required information about how to manage them. The mother trial (Kamanga et al. 2001) was set up to provide this information.

Grain Legume Production in Malawi

Other than maize, legumes are the main components of maize-based systems in Malawi. A wide range of legumes is grown in the country, either as monocrops or in association with maize. Groundnuts and beans are the most common legumes grown throughout the country. The Lilongwe-Kasungu Plains, the Mzimba-Henga Valley Plains, and the Phalombe Plains are the leading groundnut producing areas in Malawi. Pigeon pea is the most popular legume crop for intercropping with maize, particularly in the southern region. It also grows well in all free draining soils and is an important crop grown mostly by resource-poor farmers throughout the region. Soybean follows a similar trend.

The common feature of legumes is their low productivity under farmer management—yields are normally less than 25% of potential yields defined by the best research stations in Malawi, such as Chitedze (DARTS 1998). Pigeon pea and groundnuts yield about 450kg/ha and soybeans yield about 600kg/ha. Production trends show an increase in the overall production of legumes, however. For example, there has been a considerable increase in pigeon pea and mucuna production, especially since 1994 (DARTS 1998). The same report indicated that, while the proportion of maize in smallholder plantings was 70% in 1991, it dropped to 55% in 1996 in favor of pulses and oilseeds, which increased from 11% to 20%. Similarly, an economic report showed that the legume area increased by 22% and yields increased by 50% in 1995 and 84% in 1996. The increase in proportion of legumes in cropping systems also indicates that smallholder farmers are shifting from exclusive subsistence production of maize to a more flexible system that responds to greater integrated management and market opportunities (World Bank 1995). More legumes also mean increased soil fertility benefits through atmospheric nitrogen fixation and biomass decomposition.

The increase in legume production in Malawi has resulted mainly from farmer interest, especially in the southern region. Intensification of extension and research efforts focused on legume programs by the Soil Fertility Network, the Maize Productivity Task Force of DARTS, the University of Malawi, and nongovernmental organizations (NGOs) has had a large impact.

Objectives

- To enable farmers to gain experience with on-farm experimentation and to allow them to evaluate the best bet technologies for improving soil fertility through farmer experimentation.
- To work with farmers to identify different resource combinations and to assess the potential of legumes in maize-based systems.
- To enhance legume adoption by farmers in areas of low legume production.

Site and Farmer Selection

The study was conducted in Chisepo, Malawi, in 1998-2000. Chisepo is located in Kasungu, north of Lilongwe, in the mid-altitude area of the Lilongwe-Kasungu Plains (13° 32' S and 33° 31' E). The most common soils are sandy loams (60%) and sandy soils (30%). These soils are generally low in soil organic matter (0.25%), total nitrogen (0.1%), and range in pH from 5.6 to 5.8. Without soil fertility intervention the soils barely produce adequate crops. The main crops in the area are maize and tobacco. Maize yields range from as low as 0.1 t/ha to 2.5 t/ha. Annual rainfall is 600-800 mm. Figure 1 shows rainfall (mm) for Chisepo in the 1998/99 and 1999/2000 cropping seasons. Rains in both seasons occurred in November, with

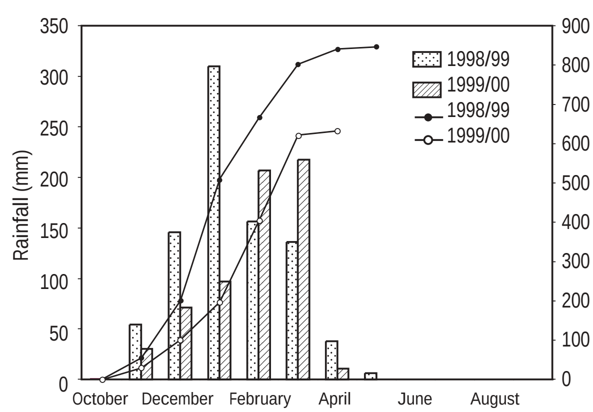


Figure 1. Rainfall distribution (bars) and cumulative rainfall (lines) for Chisepo, Malawi, 1998/99 and 1999/2000.

more rain falling in January in the first season and in February and March in the second season. In the 1999/2000 season, the late arrival of rains affected crop germination and growth. Furthermore the rains stopped early (in April), causing some of the maize to die before maturity. Cumulative rainfall in the 1999/2000 season was low: the first year total was 847.5 mm and the second year total was 633.4 mm.

Chisepo was chosen for the study because it represents the majority of lower-rainfall maize growing areas in Malawi. Also it is quite accessible by road throughout the cropping season, and farmers in the area were very interested in the research.

Twenty-two farmers were selected to take part in the study in the first year. The selection procedure was based on the list of village inhabitants provided by the village headman: every fourth farmer on the list was selected. Treatment combinations comprising four legume crops were identified through group discussions.

Trial Design

Farmers used the mother-baby approach (Kamanga et al. 2001) in the study. Accordingly, fully replicated treatments were laid in one main field, and single replicate satellite trials were established in different farmers' fields in the study area. In the mother trial, all treatments (Tables 1 and 2) were included, replicated, and managed by a researcher, while in the satellite-baby trials, farmers were given up to six treatments to manage. Management included all agronomic and cultural practices that farmers undertake to produce a good crop. The mother trial was included to obtain data for a complete statistical analysis of results and also to provide a focal point for farmers to learn from. The baby trials were farmer-managed to enable farmers to assess each treatment under their conditions and to implement the findings however they chose. Researchers thought that farmers would be able to effectively assess the treatments one by one and make recommendations for further farmer experimentation.

Treatments 1, monocropped maize without fertilizer (control), and 2, maize with 35 kg/ha N (half of the area-specific recommendation), were included for comparison with the legume-based treatments. In treatment 3, pigeon pea and groundnuts were intercropped in the first year, followed by maize in the second year. Tephrosia and pigeon pea were continuously intercropped with MH18 maize in treatments 4 and 6, respectively. In treatment 6, mucuna was grown as a monocrop in the first year, followed by maize in the second year. Characteristics of the treatment combinations are detailed in Table 2. Farmers' perceptions were obtained from discussions during the growing seasons.

No extra fertilizer or manure was applied in any treatment except treatment 2. Each plot was 10 m x 10 m with ridges spaced 90 cm apart. Maize was planted three seeds per planting station, 90 cm apart. Groundnuts and mucuna were planted one seed per planting station, 15 cm apart, while tephrosia was broadcast along the ridges at a rate of 20 kg/ha seed immediately after maize emergence. Data were collected from a net plot of 54 m^2 from each plot.

Table 1. Treatments used in the first and second years of the experiment.

Treatment	Year 1 (1998/99)	Year 2 (1999/2000)
1	Maize, no fertilizer	Maize, no fertilizer
2	Maize + 35 kg/ha N	Maize + 35 kg/ha N
3	Pigeon pea/groundnut intercrop	Maize, no fertilizer
4	Maize/tephrosia intercrop	Maize/tephrosia intercrop
5	Mucuna/maize rotation	Maize, no fertilizer
6	Maize/pigeon pea intercrop	Maize/pigeon pea intercrop

Table 2. Management descriptions and farmer perceptions of soil fertility improvement technologies used in the study.

Technology	Population density (000s)	Biological characteristics	Farmer perceptions of characteristics
Maize monocrop (control)	Maize: 37	Maize hybrid MH18, 3 seeds per planting station, 0.9 m x 0.9 m.	Current farmer practice throughout Malawi.
Maize + fertilizer	Maize: 37	Maize hybrid MH18, 3 seeds per station.	Use little fertilizer (17 kg/ha) due to cost. Gives high yields.
Maize/pigeon pea intercrop	Maize: 37Pigeon pea: 37	Temporal compatibility. Pigeon pea variety ICP 9145 planted at the same time as maize, 3 plants per planting station spaced halfway between each maize station. Pigeon pea grows slowly, which reduces competition with maize.	Pigeon pea is a bonus crop. Low density system minimizes impact on maize yields.
Mucuna rotation	Mucuna: 74	Local variety, poisonous if not properly cooked.	Difficult to intercrop at high density. Good groundcover and weed control. Not heavily attacked by pests
Year 1: Groundnut/pigeon pea intercrop Year 2: rotation with maize	Groundnut: 74Pigeon pea: 37	Groundnut variety JL 24 or CG 7 was grown in single row on ridges at 0.9-m spacings. To enhance residue biomass quantity and quality, a "bonus" pigeon pea crop is intercropped with the short duration grain legume.	Legume seed density takes into account expense of groundnut seed and farmer-adoptable seeding rates. Pigeon pea is a bonus crop.
Maize/tephrosia relay intercrop	Tephrosia: 20 kg/haMaize: 37	Temporal compatibility enhanced by planting tephrosia at first weeding. Tephrosia has an initially slow growth habit. Green manure screening studies have shown the widespread adaptability of tephrosia to Malawi agroecosystems, producing about 2 t/ha as a relay intercrop.	For a green manure system to be adopted by farmers, it must minimize labor required. Seed is broadcast along ridges and incorporated during the weeding operation.

Source: Kamanga et al. (2001).

Data Collection

Data collected from the trials were agronomic (biomass, grain yields, soil samples for nitrogen analysis, and management data) and socioeconomic (farmer perceptions and feedback). At harvest, fresh weights and moisture contents of the grains from each net plot were determined. Shelling percentages were obtained by weighing the shelled grain and the residues. These values were used to adjust the field measurements to dry matter yields. Fresh weight biomass of mucuna was measured from the net plot and adjusted to dry matter weight using the percentage dry matter weight after sun-drying the sample.

Biomass was determined to indicate the level of nitrogen incorporated into the soil by the legume. The control plot (maize without fertilizer) was used to calculate the yield gains—the yield from the control plot from each farmer was subtracted from the yield from each system. This indicated the performance of each system over that of the control and helped to assess legume performance. Maize-nitrogen ratios were also calculated to estimate the yield returns per unit nitrogen from mucuna. The ratios were obtained by dividing the total maize yield by the total nitrogen produced by the legume.

Farmers assessed the legumes through group discussions (separate male and female groups) and using field manuals, which were given to each farmer.

Farmers recorded their observations in the manuals, which were then used to compile agronomic and socioeconomic data sets. Assessment focused on legume attributes including level of use by farmers, yield, labor requirement, suitability in the system, soil fertility, and other uses. In the ranking exercise, four points were given to each attribute.

Initial Soil Conditions

Soil conditions were determined from pre-planting soil sampling at each site at depths of 0-20 cm. The sampling was important for identifying initial soil conditions in the fields. The information was used to quantify the legumes' contribution to the soil over the season.

Results show that the soils were low in nitrogen, organic matter, and organic carbon (Table 3). The values indicate that the soils could not support most crops with high nitrogen requirements such as maize. They also highlight the need for integrated nutrient management to improve soil fertility. The most common soil class was sandy clay loam with a moderately acidic pH value of about 5.6.

Biomass Production

Legumes contribute to soil fertility in two main ways: 1) by biologically fixing nitrogen from the atmosphere and 2) by recycling nutrients from deeper soil profiles upon decomposition. Either way, biomass accumulation by the plant is crucial and needs to be maximized because the nitrogen content of most legumes is only 3%.

Mucuna was incorporated at peak flowering in March. Biomass measurements ranged from as low as 500 kg/ha to almost 14,000 kg/ha (Figure 2). Tephrosia and pigeon pea biomass were not measured at the time of incorporation in all baby trials.

Farmers wanted to harvest grain from the long duration pigeon pea ICP 9145. This type of pigeon pea is left growing in the field after maize has been harvested and is grazed by unattended livestock. In some fields, pigeon pea and tephrosia were eaten and destroyed by livestock, mainly goats, resulting in very low grain and biomass yields. Farmers that protected their crops harvested more grain and incorporated more biomass.

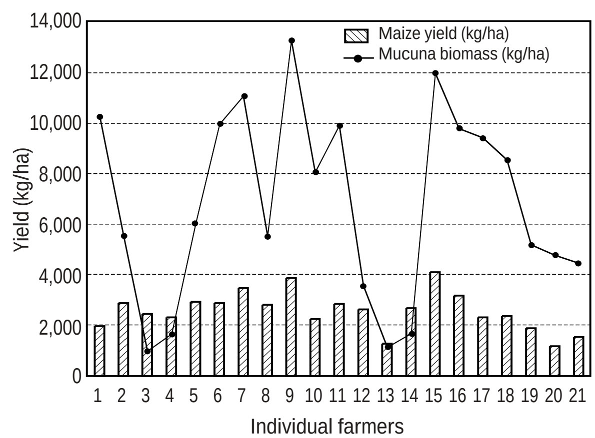


Figure 2. Effect of incorporating mucuna biomass on maize yield.

Table 3. Initial soil conditions of the 0-20 cm soil layer in Chisepo.[1]

	Parameters					
Treatment	**NO_3 (ppm)**	**NH_4 (ppm)**	**OC (%)**	**OM (%)**	**WC (%)**	**pH**
Maize monocrop (control)	**0.15**	**0.66**	**0.25**	**0.16**	**0.12**	**5.5**
Maize + fertilizer	0.22	0.91	0.15	0.14	0.15	5.6
Pigeon pea/groundnut intercrop/maize rotation	0.17	1.20	0.21	0.14	0.18	5.6
Maize/tephrosia intercrop	0.11	1.14	0.20	0.08	0.12	5.7
Mucuna/maize rotation	0.18	1.24	0.11	0.07	0.11	5.8
Maize/pigeon pea intercrop	0.17	1.40	0.19	0.06	0.16	5.6
Average	0.17	1.09	0.19	0.11	0.14	5.6

[1] Soil sampling was performed to a depth of 120 cm at pre-planting and harvesting in both seasons.

Improving Soil Fertility through Biomass Incorporation

Myers et al. (1997) reported that the incorporation of organic inputs, as opposed to surface application, accelerates the release of nutrients and hence increases uptake by subsequent crops. Figure 3 shows that the amount of organic nitrogen in the soil from incorporating mucuna was as high as 400 kg/ha N in the study. In a hypothetical situation this is a tremendous achievement; however, in reality this is not the case because of several factors ranging from slow decomposition to poor synchronization of uptake by the growing crop (Giller and Wilson 1991). This means that the net benefit of incorporated nitrogen in terms of yield gains may increase or decrease based on how the residues are managed (Jones et al. 1997; Becker 1997). For example, a mixture of organic residues applied to the soil increases plant use efficiency (Becker 1997). Gilbert (1997) noted that almost 50% of the nitrogen from incorporated residue is sufficiently utilized by plants over a season. Considering the information given in Figure 3, a farmer still stands to gain most benefit from incorporating biomass. With the exception of a few farmers, most produced more than 50 kg/ha N—the equivalent of four 50-kg bags of calcium ammonium nitrate (CAN-21% N), which cost about MK 4,400.00[1] from the market. Since the average fertilizer use by smallholder farmers in Malawi is only 17 kg/ha N (Snapp et al. 1999), the inclusion of legumes in the farming system has obvious benefits.

Grain Yield

Maize. The yield of a crop is a measure of performance or response to production factors. In the study, the maize yield represents the response of the crop to residual nitrogen in the second season. Table 4 shows the maize yields in the first and second years of the study. Maize yields in the first year were variable. Maize/tephrosia produced the highest yield, outperforming the maize + fertilizer treatment. The

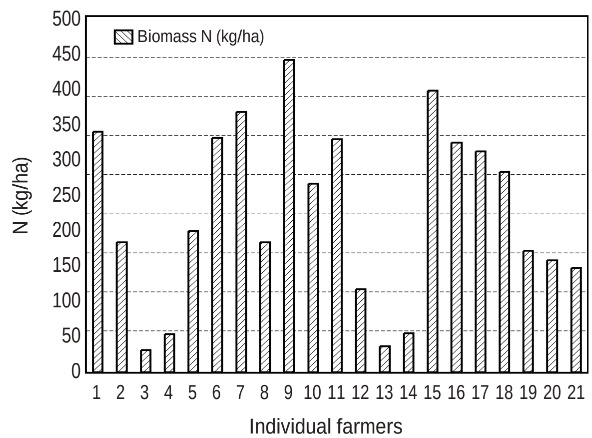


Figure 3. Effect of incorporating mucuna biomass on soil nitrogen levels.

Table 4. Effect of residual legume nitrogen on second-year maize yields (kg/ha) in Chisepo.

Treatment	Year 1998/1999[1]	Year 1999/2000	Yield increase over control (%)
Maize monocrop (control)	939	1003	-
Maize + 35 kg/ha N	2200	2206	120
Pigeon pea/groundnut intercrop/maize rotation	-	1788	78
Maize/tephrosia intercrop	2561	1599	59
Mucuna/maize rotation	-	2461	145
Maize/pigeon pea intercrop	1484	1752	74
CV (%)	147.3	20.0	
SE ± (treatments)	384.8	79.7	

[1] There was no residual N in the first year; yields in the 1999/2000 were a response to residual N.

[1] Exchange rate US$ 1 = MK 80. (MK = Malawi Kwacha)

maize/pigeon pea intercrop treatment also gave reasonable yields compared to the control plot in the first year. These results were not a surprise and could be explained by differences in farmers' field management. Farmers that had a good history of field management produced good maize growth and higher yields due to the effect of residual nitrogen. In the second year the maize response to residual nitrogen was good. The highest response (P=0.001) was measured in mucuna/maize rotation plots, which produced an average yield of 2460.6 kg/ha. The maize + fertilizer treatment had the second highest response, followed by the groundnut/pigeon pea intercrop (in rotation with maize), the maize/pigeon pea intercrop, the maize/tephrosia intercrop, and finally the control maize plot.

The results show that mucuna was the most beneficial legume to maize yield (Figure 4). In general, though, there was a good response from all of the legumes in terms of maize yield, indicating that legumes have a large potential for reducing food insecurity. Legume biomass was incorporated in the first year, which most likely improved soil fertility through nitrogen fixation and litter decomposition, as illustrated by the maize response. The maize yield associated with each technology determines whether farmers can achieve food sufficiency, which in turn influences their choice of technology.

Maize yield gain or loss is calculated by comparing the yield from each treatment with that of the control plot. In the study, maize yield gain was highest in the mucuna plot, followed, on average, by the pigeon pea/groundnut intercrop in rotation with maize (Figure 5). These trends in yield gain highlight that mucuna is the best legume for improving soil fertility among those tested and that the yield gains from mucuna are justifiable whether farmers incorporate or harvest the seed (Sakala et al. 2001).

In some farmers' fields, however, there were net losses in yield. This was common in the maize/tephrosia plots, suggesting that technology performance depends on how farmers manage different fields. Similarly, Gilbert (1998) and Kumwenda et al. (1997) reported maize yields of more than twice those of unfertilized maize intercropped or in rotation with legumes in Malawi. Farmers with a strong interest in legumes invest more in their management, while those with little interest may not do so. At the same time, however, given uniform management, different legumes do better in certain soil types.

Based on the mucuna yields produced and the amount of nitrogen incorporated by farmers in the study, maize-nitrogen ratios were calculated for individual farmers. The maize-nitrogen ratio gives an

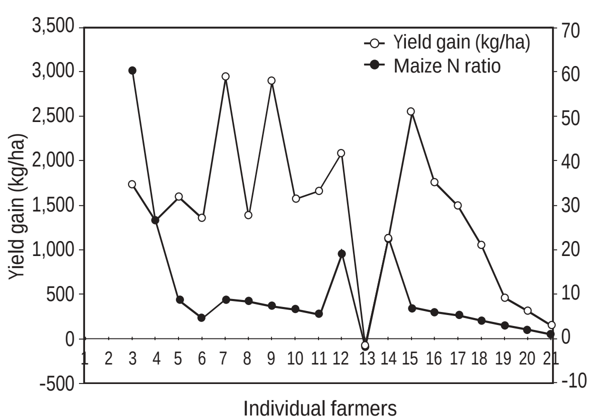


Figure 4. Effect of mucuna use on maize grain yield and maize-N ratio.

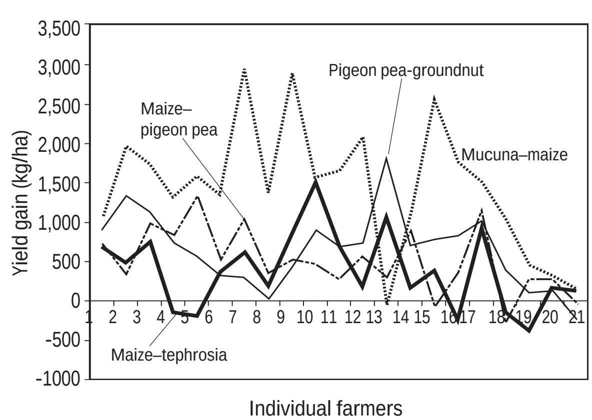


Figure 5. Maize yield gain in four legume-based cropping systems, Chisepo, Malawi.

indication of how much extra maize would be obtained per extra kilogram of nitrogen from legumes incorporated into the soil. In this case, the maize-nitrogen ratios were encouraging, given that not all of the incorporated nitrogen was used during the season. An implication of the maize-nitrogen ratio is that if farmers increase the land under mucuna or other legumes, the yield return expected from maize in the second year will be within the projected range. This prompts the question of what merits do the maize-nitrogen ratios have for smallholder farmers? The answer is that the higher the maize-nitrogen ratio, the better the system operates in terms of food security.

Legumes*.* The legumes also performed well in terms of grain production in both years. Pigeon pea and groundnuts have national average yields of 450 kg/ha (DARTS 1998), compared to potential yields of 2,500 kg/ha and 4,000 kg/ha, respectively. Farmers in Chisepo achieved legume yields within the national average, so there is much room for improvement. Having said that, the yields obtained were encouraging given that pigeon pea is a new crop in the area. Yields shown in Figure 6 indicate that, on average, pigeon pea performed well in all of the intercropping treatments. In the study, pigeon pea and groundnuts benefited farmers by both increasing grain yield and improving soil fertility.

Farmer Evaluation of Legume-based Systems

Groundnuts, cowpea, beans, and bambara nuts are legumes traditionally grown by farmers in the study area, while pigeon pea, groundnuts (CG7 variety), tephrosia, and mucuna are introduced. Farmers compared the attributes to food security of the new and traditional legumes.

Legume use*.* Farmer discussions identified a number of uses of legumes and associated constraints, particularly of traditional legumes (Table 5). In the first year, farmers were not sure of the benefits of the introduced legumes, but by the second season a number of uses had been identified. A legume that has the potential to address a number of household issues such as food security and soil fertility improvement also has a good chance of being adopted. For example, in southern Malawi pigeon pea is commonly

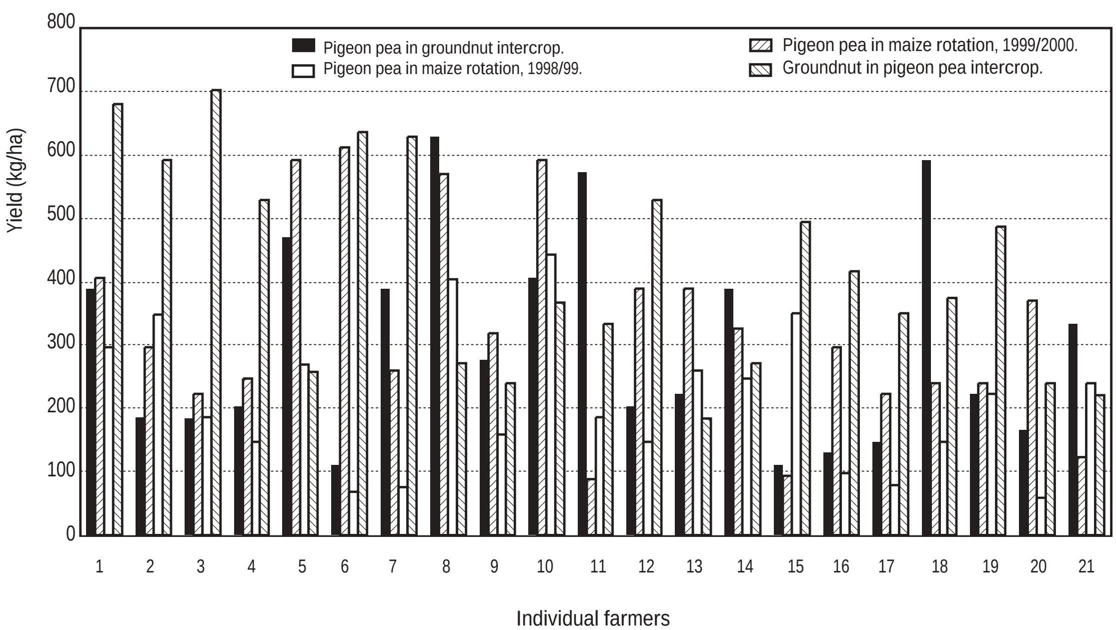


Figure 6. Grain yield of pigeon pea and groundnuts in four legume-based cropping systems, Chisepo, Malawi.

Table 5. Legume use and associated constraints in Chisepo.

Legume	Uses	Constraints
Groundnuts	Food Sale Animal feed Rotation Soda substitute (for burning)	Best as a monocrop
Cowpea	Food *Chipere* Sale	Storage problems (weevils) Low production
Bambara	Food Sale	No intercropping Seed not available Small market
Pigeon pea	Food Soil fertility improvement Tobacco racks in burns Medicine (ear ailments) Weed suppression	Seed not available Goats eat it Market not available Late maturing
Mucuna	Kills witchweed Soil fertility Food	Kills maize Needs more land Requires more time and firewood for cooking Poisonous Requires more labor Seed problems
Tephrosia	Kills witchweed Medicine Improves soil fertility	No food value Difficult to cut Seed not available

Source: Farmer group discussions.

intercropped with maize for food and for sale. In addition, farmers now realize that the crop also improves soil fertility and provides animal feed, firewood, and material for minor construction. These uses have popularized the crop in the area.

Of the traditional legumes, farmers said that groundnuts were the main legume grown in the area. They also noted that pigeon pea would soon follow the same trend. Table 5 shows that both traditional and introduced legumes have multiple uses. All legumes, except tephrosia, have food value, but are prepared in different ways. Groundnuts are eaten raw, or the pods can be cooked, roasted and/or salted, roasted and pounded to make butter, made into relish, or used to season other dishes. The grain can be ground to add to a variety of dishes such as rice meal, maize porridge, and local confectioneries. Pigeon peas are eaten green as a snack, dry as a paste, and as relish. Cowpea leaves are used to make a vegetable relish and the grain is used similarly to pigeon peas. Legumes provide a cheap source of protein, no matter how they are prepared and consumed.

Legumes improve soil fertility in two ways. The first is through the conversion of atmospheric nitrogen by nodules on the roots. The nodules form a symbiotic relationship with rhizobia that have the capacity to change atmospheric nitrogen into a plant-useable form in the soil. When the plant dies, the nitrogen in the nodules is left in the soil for use by the following crop. The amount of nitrogen produced by the nodules depends on the state of relationship in the roots and the health of the plant. The second way that legumes improve soil fertility is by accessing nutrients in deep soil layers. Nutrients are washed down through the soil profile by the vertical movement of water. The nutrients that accumulate in the bottom layers are not accessible to most shallow rooted plants like maize. Deep rooted plants such as pigeon pea are able to reach and mine these nutrients for processing. Again, upon plant death and decomposition, nitrogen is released to the top soil layers. Shallow rooted crops are then able to take advantage of this nutrient recycling from deeper soil layers. A cropping system based on intercropping legumes is therefore capable of being sustainable if well managed.

Apart from providing food and soil fertility benefits, legumes are also a major source of income to farmers. Most legumes including groundnuts, beans, and soybeans are sold to the Agricultural Development and Marketing Corporation (ADMARC), private traders, and other outlets. Some legumes such as mucuna, cowpea, bambara nuts, and chickpea are sold locally fresh, dry, or cooked. In the southern region of Malawi, mucuna is one of the main legumes that is prepared fresh and sold as a snack in the local markets. Despite the labor involved in cooking the legume, it enables farmers to answer immediate cash needs.

Constraints on legume use*.* Several constraints on legume use were mentioned by farmers in the study. The main constraint was the lack of availability of seed of the introduced legumes (Giller et al. 1994; Kumwenda et al. 1996). Mucuna, for example, was incorporated early in the trials, which meant that farmers had no seed left afterwards. Damage by animals was another constraint. The seed yield of some pigeon pea plots was reduced due to animal grazing. This is a major concern, particularly where the legume variety matures late, coinciding with the time that livestock are left to graze without supervision. Legumes need to be protected from livestock to maximize their soil fertility and grain yield benefits.

The main constraint on using mucuna is that it contains high levels (2-6%) of L-dopa (Lorenzetti et al. 1998), which is deemed poisonous if more than 1.5 grams are consumed per day. To remove the L-dopa, the seed needs to be boiled several times, discarding the water each time. For this reason, mucuna preparation classes were conducted with farmers. During the exercise two further constraints were pointed out—mucuna requires much time and firewood (which is becoming difficult to find in the area) before it can be eaten. The estimated cost of preparing the mucuna was reported to be 10 times the sale price of the seed (Gilbert 1998). However, when farmers tasted the prepared mucuna, they found it pleasant. The village headman remarked that "Despite the problems of cooking, the mucuna is a nice meal and is good eating it without the *nsima* and gets the stomach full." (Nsima is the local name for the main dish made from maize in Malawi.) Another issue was that mucuna was found to climb and shade nearby maize plants, which made farmers conclude that it was not suitable for planting at high densities at the same time as maize in intercropping systems. The main constraint on using tephrosia was that it had no food value.

Labor requirement. Tobacco plays a large role in the smallholder farmer's economy in the area, being grown by over 80% of farmers (Snapp et al. 1999). Those who do not grow the crop provide labor in one way or another for tobacco production. To obtain a good crop, tobacco requires early planting, and timely weeding, fertilizing, and harvesting. At the time of tobacco planting, maize and other crops, including legumes, are also planted and can cause labor conflicts. Not surprisingly maize and tobacco are given a high priority among the crops and consequently receive a substantial labor allocation. Pigeon pea intercropped with maize may not cause a problem because the legume is planted at the same time as the maize. In southern Malawi, some farmers mix pigeon pea seed with maize seed prior to planting, which eliminates the time needed for planting the legume separately. Like cowpea, tephrosia can be broadcast at planting or first weeding, although this is associated with poor germination.

Mucuna is the most difficult of the legumes because it needs to be planted separately. Moreover, farmers planning to plant tobacco in the study area found that it coincides with the time of mucuna planting. This conflict could be solved if farmers had access to sufficient labor for mucuna establishment. Farmers with no tobacco, however, would be able to plant mucuna immediately after their main crops.

Incorporation of mucuna was another issue identified by farmers because it coincides with the peak tobacco-picking period. Farmers in the area said that they would not leave tobacco picking to tend to the mucuna. The overall assessment by farmers indicated that all legumes in intercrops require less labor than those planted separately. Mucuna requires more labor for planting and incorporation, while legumes in intercrops benefit from the labor allocated to the main crop.

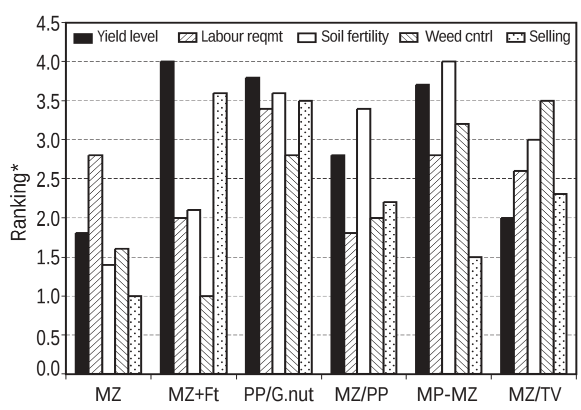
Soil and field types. Farmers also assessed legume suitability in terms of soil and field types, using farmer-derived categories. Soils in Chisepo are mainly sandy soils, which occur in about 96% of fields, and red sandy loams, which occur in 14%. Fields range from vlei margins to toplands. Most farmers planted legumes in the sandy soils.

Pigeon pea and tephrosia grew well in the sandy soils, especially in the vlei margins where the soils were relatively moist after maize harvesting. However, pigeon pea did not do well in the topland fields with quick-drying red soils, or in waterlogged fields. Mucuna did very well in all field types, but performed best in well drained, sandy loams.

Farmers' legume preferences. An overall ranking of the legume-based systems was performed by separate male and female farmer groups (Figures 7a,b). Differences in priorities were observed between the groups: the female farmers placed emphasis on systems with high food potentials, while the male farmers focused on soil fertility issues. Overall, however, the male and female rankings agreed on all aspects, though the two groups gave different scores to the attributes. Both groups agreed that the fertilized maize treatment was superior in terms of yield, followed by the mucuna treatment and pigeon pea/groundnut treatment. Mucuna was ranked highest for improving soil fertility by both farmer groups, and the pigeon pea/ groundnut treatment was ranked second. These two systems were also ranked highest for weed control. Overall the pigeon pea-based system was preferred by both groups, though there was a striking difference between groups in how they ranked it. Female farmers were more interested in the food diversity offered by the system and gave it a higher value than male farmers, who seemed to concentrate on the maize yield only. Mucuna was ranked highly by male farmers for its potential for reducing fertilizer use.

Unlike mucuna, pigeon pea satisfies all farmer categories because it requires less labor, is suitable for intercropping, and is harvested when little else needs to be done in the field. Furthermore pigeon pea does well in poor soils. Mucuna is best suited to farmers that have more land and labor. Those with limited area would have to intercrop mucuna with maize at very low

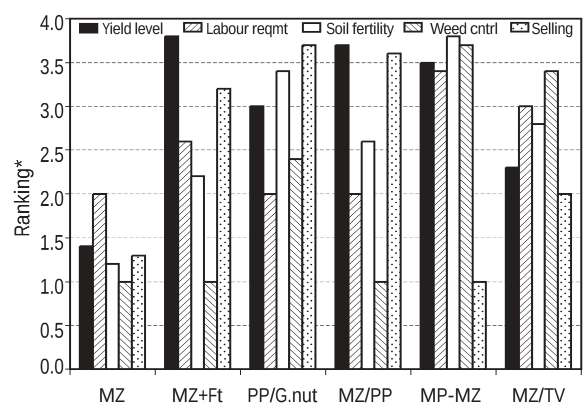
a.



* Rating scale: 1 = very low, 2 = low, 3 = high, and 4 = very high.

MZ = Maize control
MZ+Ft = Maize + fertilizer
PP/G.nut = Pigeon pea/groundnut
MZ/PP = Maize/pigeon pea
MP-MZ = Mucuna - maize
MZ/TV = Maize/tephrosia

b.



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MP-MZ = Mucuna - maize
MZ/TV = Maize/tephrosia

Figure 7. Ranking of legume-based cropping systems by (a) female and (b) male farmer groups in Chisepo, Malawi.

planting density, thus reducing its soil improvement effects. How, then, can such farmers benefit from growing mucuna?

The Risk Management Project has joined other researchers to explore ways of intercropping mucuna with maize. The most important issue to be solved is the optimum time of establishing mucuna in the maize crop. Gilbert (1998) reported that mucuna introduced six weeks after maize planting did not heavily affect the maize, and biomass yields were reasonable. However, a later introduction of mucuna did not produce any meaningful benefits. These findings still need to be validated over different farmer categories, land types, and seasons.

Farmers were less interested in growing tephrosia. They appreciated its soil fertility improvement and weed control benefits, but were put off by its lack of food, market, and feed values.

Conclusion and Future Directions

Through the research conducted in Chisepo, we can answer the question of whether legumes can make a difference to maize production. Farmers in Chisepo obtained encouraging yields from maize-based legume systems. However, the question of whether the benefits are sustainable still remains. More research needs to be conducted on the many legume issues identified by farmers in this study. First and foremost is seed availability. If access to seed does not improve, very little progress will be made. Another issue that requires more research is the suitability of legumes as intercrops, with emphasis on timing of planting. Despite this, farmers indicated that even without the influence of researchers, they would plant more land to legumes, either as intercrops or as monocrops (mucuna). Research also needs to be conducted into the integration of legumes into tobacco systems. Most tobacco farmers in the area use very little fertilizer. If farmers could see soil improvement and, hence, yield benefits from legumes, the rate of legume adoption in the area would increase.

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