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Abstract: Soil fertility is an important limiting factor for smallholder agriculture in southern Africa. In 1999-2002 research was undertaken to identify and evaluate legume technology options for soil fertility improvement within the context of farmers' livelihood and risk management strategies in Zimuto, Zimbabwe. Specific objectives included assessment of legume performance by land type, identification of legumes that best replenish soil fertility, and assessment of legume suitability in intercropping systems under smallholder conditions. Legumes were grown in both single crop and maize intercrop systems. Performance criteria were established through group discussions with farmers, and legume performance was later evaluated according to these criteria. Evaluation of legumes varied somewhat according to gender. Mucuna was found to be the overall most desirable legume for a single crop system, while pigeon pea and grahamiana were most desirable for the intercrop system. The greatest challenges in establishing legumes was found to be soil fertility and diseases and pests.

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On-Farm Legume Experimentation to Improve Soil Fertility in the Zimuto Communal Area, Zimbabwe: Farmer Perceptions and Feedback

Introduction

Low soil fertility has been identified as a fundamental biophysical constraint to agricultural production in southern Africa (World Bank 1989; Sanchez et al. 1997). In Zimbabwe, the problem has been made worse by the legacy of colonial land policies. Smallholder farmers were concentrated into communal lands to grow maize on sandy soils with few soil fertility inputs. The soils in these areas are generally derived from granite and gneiss, producing inherently infertile (Grant 1981) coarse-grained sands with less than 15% clay. These soils are also low in nitrogen and phosphorus (Mashiringwani 1983), and successful production of food on them requires the use of N fertilizer (Grant 1970; Waddington et al. 1991). Nevertheless, because of the increasing costs of inorganic fertilizers, farmers have attempted to supply the much-needed nitrogen in the soil by complementing them with traditional fertilizers such as animal manure. Declining manure quantities and quality, however, have meant poor and very variable responses (Mugwira and Murwira 1997) and relatively low food production in smallholder agriculture (FAO 1999; Low and Waddington 1991).

Demand for food is increasing with population growth, resulting in a continuing challenge to produce enough food to adequately feed families in the region (McCalla 2000). Without modification of current practices or the identification of new options for smallholder agriculture, food production will continue to decline in per capita and per unit area terms. Reeves (1998) pointed out that no single method of farming in any region remains sustainable without change. In support, a review of recent literature (Loehman et al. 1994; Low and Waddington 1991) indicates a growing awareness that methods for soil fertility improvement need to be dynamic in order to meet the evolving challenges of farmer societies. Present production methods in smallholder agriculture need to be modified to identify options that can sustainably replenish soil fertility and increase maize yields. Farmers are also seeking change, as indicated by the support they give to on-farm research in Zimbabwe. One example is the efforts of farmers to help develop legume-based technologies in Zimuto, southern Zimbabwe. The legumes improve soil fertility (Sakala et al. 2001) and add diversity to the food options for farmers (Gilbert 1999; Kumwenda and Gilbert 1998). In Zimuto, farmers who participated in focused discussions ranked soil fertility as the most important issue, although the legumes used in the study were chosen for their potential to provide a wide range of uses.

Objectives

This research was conducted to identify and evaluate legume technology options for soil fertility improvement within the context of farmers' livelihood and risk management strategies in Zimuto, Zimbabwe. Specific objectives were

- Assess legume performance by land type
- Identify legumes that best replenish soil fertility
- Assess legume suitability in intercropping systems under smallholder conditions

Methods and Materials

Site selection and group formation

Zimuto is a dry area of south-central Zimbabwe. It is located in Zimbabwe Natural Region IV and has a unimodal rainfall season from October to March; average rainfall is 631 mm with a range of 200-1,000 mm. Rainfall comes in sporadic convectional storms with a 30% chance of a mid season drought in January or February (Hagmann 1995). Agriculture in the area is rain-fed with little wetland irrigation. The soils are predominantly sandy and are formed from granite. They have a low moisture holding capacity, a low PH, and little organic matter or nitrogen. Soils are characterized by their position in the catena, and can be divided into topland, vleis, vlei margins, and homestead. The differences in the soil catena can influence the type of management and resource use for a piece of land–for example, about 60% of all manure is applied to the vleis. The dry topland granitic soils of the upland ridges and valley slopes are well drained and moderately shallow, and are comprised of coarse to medium grained, dark yellow or brown sands and sandy loams. In addition to maize, the topland fields are planted with cowpea, bambara, groundnut, millet, sweet potatoes, and other minor crops largely for home consumption. The vleis are shallow to moderately drained, and consist of dark brown coarse-grained sands, ranging from loam sands to clay loams. Other crops currently grown on the vleis are groundnut, rice, and bean. Wetland crop production of wheat and vegetables during the cool dry season is also done on the vleis. The vlei margins are moderately deep and imperfectly drained, and consist of dark brown coarse sands with mottling below 0.5 m. The homestead field type is located on flat ground close to the homestead. It is composed of well drained, moderately shallow coarse to medium grained yellow or brown sands and sandy loams. Due to its proximity to the kraal, it is also close to manure, compost, wood ash and homestead labor sources. The homestead is drought prone in poor rainfall seasons and may suffer leaching in wetter seasons. Groundnuts, bambara, rapoko and root vegetables are produced in addition to maize, often in rotation.

The farmer groups involved in this study were formed from the communities that work with CARE International on the conservation of dam catchment areas. In discussions intended to identify agricultural problems, these farmers named soil fertility as the most important constraint to agricultural production. Discussions were then focused on identifying cheap and sustainable ways to improve soil fertility. A small group of 14 farmers was then formed in the village of Chikato to conduct on-farm legume trials in the fields. According to the Country Almanac (1998) Zimuto's conditions are similar to 40% of the country's area, indicating that the results of the studies could easily be applied elsewhere.

Context and trial design

The project started in the 1999/2000 growing season with 14 farmers. Nine legumes were tried on-farm using the mother-baby approach developed for farmer assessment of legumes in Malawi (Kamanga et al. 2000). The project introduced four new legumes: *Mucuna pruriens* (velvet bean or mucuna), *Crotalaria grahamiana* (grahamiana), pigeon pea, and sunnhemp. Five traditional legumes (spreading cowpea, bunch cowpea, bambara, groundnut, and soybean) were also used.

Four mother trials were implemented, each managed by three or four farmers. A mother trial had 18 plots (each measuring 10 m x 20 m) arranged in a way that made it easy to compare an intercrop and a single crop system for each legume. Table 1 shows the simple comparison layout of the legumes in the mother trials. Two mother trials were set up on homestead fields and another two on the topland fields in order to compare the performance of legumes across these two land types. Baby trials were subsets of the mother trials and were individually managed by each farmer. Farmers chose four legumes to plant in their fields as baby trials. Details of farmer legume choices are shown in Table 2. All legumes except mucuna were planted at the same time as maize when intercropped. Intercropped mucuna was planted six weeks after maize because previous research had shown a tendency for it to climb up maize plants and pull them down if planted too early (Gilbert 1998).

The planting of legumes in the mother trials followed agronomic specifications developed from previous work by Soil Fert Net members

Table 1. Mother trial plot layout and legume assignment, 2000/2001

Mucuna	Sunnhemp	Grahamiana	Pigeon peas	Bunch cowpeas	Spreading cowpeas	Soybeans	Groundnuts	Bambara
Maize-mucuna	Maize-sunnhemp	Maize-grahamiana	Maize-pigeon peas	Maize-bunch cowpeas	Maize-spreading cowpeas	Maize-soybeans	Maize-groundnuts	Maize-bambara

Table 2. Farmer legume options and field type

Farmer's name	Legume Variety							
	Pigeon peas	Soybeans	Bambara	Groundnuts	Mucuna	Sunnhemp	Grahamiana	Cowpeas (spreading)	Cowpeas (bunch)
M. Dowa		H			VM	VM	VM		
Z. Zvokuenda									
R. Nyenyai		T			T	T	T		
A. Paringira	G	T			T	T	T		
N. Chitima			T		T				H
J. Zireva	VM	T	T		T				
D. Matsvange		T			VM			T	T
S. Mupunza		T	T	T	T				
D. Madhoro		T		T	VM				
J. Chiramba					H/VM	H/VM	H/VM		
K. Chigiya					T	VM		T/VM	T
M. Chishere		T			H/VM				T
N. Mudakuenda			T	VM	T				T
F. Nguvo				H	T				H

Legend: V = Vlei; VM = Vlei margin; H = Homestead; T = Topland.

Key

	Maize-legume intercrop
	Legume single crop

(Waddington et al. 1998) as shown in Table 3. To reduce competition, the spacing was changed for grahamiana, soybean, bambara, groundnut, and mucuna. Grahamiana and sunnhemp had poor germination in the first year, leading farmers to change the depth of planting from 5 cm in the first year to near the soil surface in following years. Other legumes were planted as in the first year, when they were drilled and covered with soil. Because of poor soils, the phosphorus-based fertilizer Single Superphosphate was applied to all legume soils in order to stimulate root development and growth.

Agronomic field data sheets. With the help of enumerators, farmers were given field data sheets to record activities and observations throughout the season. The sheets indicated the farmer's name, plot layout, and treatment assignment, as well as rainfall received, dates of operations, plant count, yields, soil sampling, and farmer comments over the year. A checklist of the enumerator's responsibilities was also included. In addition, the enumerator assisted farmers in measuring yields.[1]

Resource allocation maps (RAM). Resource allocation maps are useful management tools for farmers and were used to collect information about their farming methods. With the help of an enumerator, each farmer drew maps of their fields as they stood in 1999 and indicated how resources had been allocated to different field types. The RAMs indicated household members, amounts and routes for resources, dates of operations, labor use, and harvested crops. They were updated several times in 1999 through 2001, and they form a good platform for group discussions and decision-making on resource allocation by farmers. Figure 1 shows one of the maps developed by farmers in the area.

Group discussions and performance criteria

Group discussions were used to elicit perceptions about the trials beyond what was included in the field data sheets. They involved 14 farmers, nine female and five male. The discussion groups were held in all-male and all-female groups as well as in a mixed group that included all farmers. These group discussions were held on several occasions with very

Table 3. Planting pattern and seed rates of legumes in mother trials

Legume	Single crop system (cm)	Intercrop system (cm)	Seed rate kg ($20x10m^2$)
Pigeon pea	90 x 30	90 x 30	3
Soybean	20 x 5	20 x 5	4
Bambara	40 x 20	40 x 30	8
Groundnut	30 x 20	40 x 20	8
Mucuna	50 x 25	90 x 25	20
Sunnhemp	40 x 10	90 x 5	3
Grahamiana	40 x 10	90 x 5	8
Spreading cowpea	90 x 30	90 x 30	5
Bunch cowpea	40 x 20	40 x 20	10

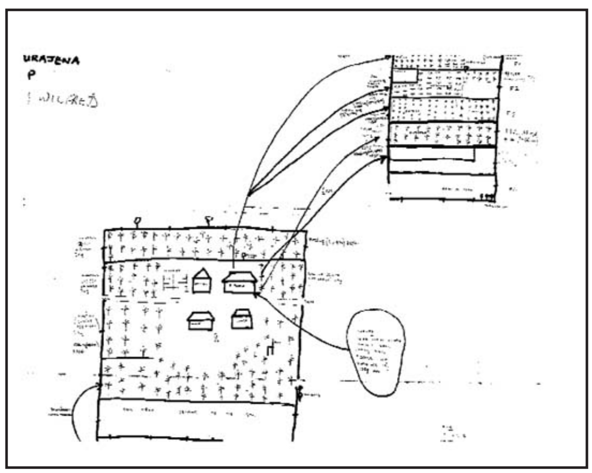


Figure 1. Sample resource allocation map.

[1] Note that the yields cited in this paper are averages from the four mother trials.

little variation in attendance, and were supplemented by individual interviews with farmers. Farmers used the discussions to outline their perceptions of the trials and provide feedback on their performance. These views are discussed in subsequent sections of this paper. As a part of the discussions, farmers participated in a ranking exercise that identified the following criteria for evaluating the performance of the technologies:

Yield level. Farmers said that the research focused on improving the yield of crops, especially maize, through the use of legumes. Legumes incorporated into the systems should increase maize yields in the same season or in subsequent years. The impact of legumes on soil fertility restoration depends largely on the volume of biomass the legume produces (Gilbert 1998; ICRISAT/MAI 2001). Some farmers had good biomass production in the first year, and this encouraged other farmers to view biomass as an important characteristic for identifying legumes that would perform well and help the poorer soils.

Drought tolerance. Because of the drought that often occurs mid season, some legumes were affected by moisture stress. Farmers found that such legumes may not be suited to the dry conditions that frequently occur, and that legumes capable of tolerating harsh conditions may be more suitable for the environment in the area. In evaluating the legumes, tolerance to drought was included in the criteria.

Food and feed value. The first concern of farmers was how to produce enough food from the degraded soils. Using legumes for soil fertility improvements is a good alternative for achieving that goal, but adoption of legumes for soil fertility would be higher if the legumes also provided additional food for the farmers. In addition, farmers said that legumes should provide animal feed to improve the milking potential of cows.

Labor. Labor is another factor that affects the incorporation of legumes into smallholder farming systems. Farmers said that legumes should be compared to identify those that need less labor.

Intercrop suitability. As a staple food, maize is usually produced in an intercrop system-farmers said that very few crops were planted in single crop systems. To suit these methods, new crops should be evaluated on their performance in intercrop systems.

Results

First year (1999/2000): Farmers' capacity to experiment

The value of land and the importance of maize caused most farmers to avert risks by planting legumes on their poorer fields. Sixty percent of the farmers used poor lands (such as previously fallowed topland), producing low germination and growth rates. The remainder of the farmers planted the legumes on fields that had received animal manure. The response of legumes on manured fields was also varied because the application of fresh manure on some fields affected germination and growth. Farmers attributed the reduced germination rates on those fields to heat produced from decomposing manure.

Almost no legumes planted in the vleis grew well. In particular, mucuna was affected by waterlogging. The legumes also did poorly in heavily depleted topland sands, although they showed some potential to improve soil fertility when planted on better quality topland. In addition, farmers made an important observation regarding mucuna on these fields. It was found that mucuna plants twine up maize plants that border it. This led farmers to question whether to plant mucuna and maize at the same time in an intercrop system. However, through group discussions on the first year of legume performance, farmers chose to intercrop the legume with maize as a relay crop, planted six weeks after planting maize.

Noting poor germination and growth for grahamiana, sunnhemp, and other small seeded legumes in the first year, farmers reduced their planting depth from greater than 5 cm to near the soil surface. In the second year, germination and growth were improved by only using well-decomposed manure. Broadcasting some of the legumes also affected germination, causing farmers to change to hole and drill planting methods. However, farmers noted that these methods require more labor than broadcasting the seed. In general, all crops had better germination in the first year when planted as single crops rather than intercropped.

In all, farmers evaluated legumes as having a high potential to improve soil fertility. More farmers requested to join the group or to obtain seed following the first year. The project has started a program to increase the seed supply of legumes in the 2001-2002 cropping season through collaboration with CARE International. However, the demand for the legumes has become so large that there is a need to further increase seed production through participating farmers.

Second year (2000/2001): Implementation of changes

The germination of legumes improved after implementing the changes from the first year, with those planted on homestead fields doing the best. This was especially true when homestead fields received well-decomposed ma. Table 2 gives details regarding the types of fields used for the baby trials in 2000-2001.

Rainfall in the 2000/2001 season. Figure 2 shows rainfall records from the farms for the 2000/2001 crop season. Total rainfall was 593 mm that year, about 50 mm below average. The rainfall started in November and was followed by a long mid-season dry spell that lasted for eight weeks, through the end of January. This period was crucial to the farmers for timely application of top dressing fertilizer, weeding, and the planting of legumes in intercropping plots. The dry spell in January reduced the growth of legumes through moisture deficits, aphid attacks, and a delay in the planting of intercropped legumes. Farmers found that sunnhemp, groundnut, and cowpea were greatly affected by moisture stress. In addition, aphid attacks destroyed bunch cowpea, groundnut, and bambara nut. Although there was over 500 mm of rainfall in February and March, the crops had already been damaged by then. The maize was flowering at that time and some crops died from moisture stress. Maize that had been planted early matured around this time and started to rot in the fields–especially ears of SC-501, which has a poor husk cover.

Biological performance of legume systems. Poorly distributed rainfall affected timely operations by farmers, crop growth, and yield performance in the season. Farmers evaluated the legumes to identify those that could withstand harsh conditions and provide a yield for the farmers despite the stresses. Two parallel measurements were made from single crop and intercrop plots. The results (Figures 3 and 4) show that some legumes are best suited to intercropping systems while others do better when grown as single crops.

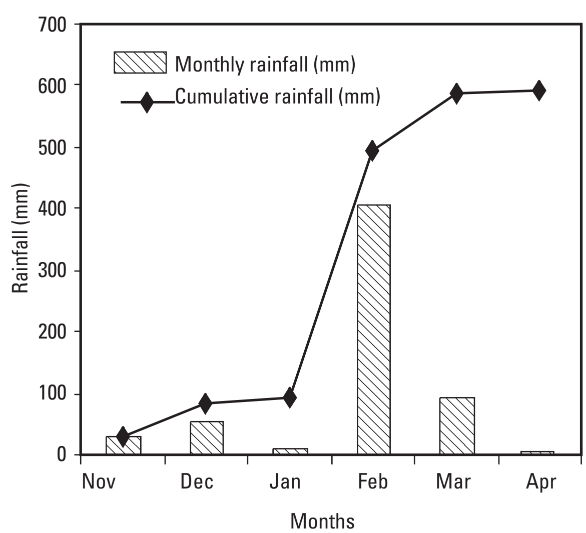
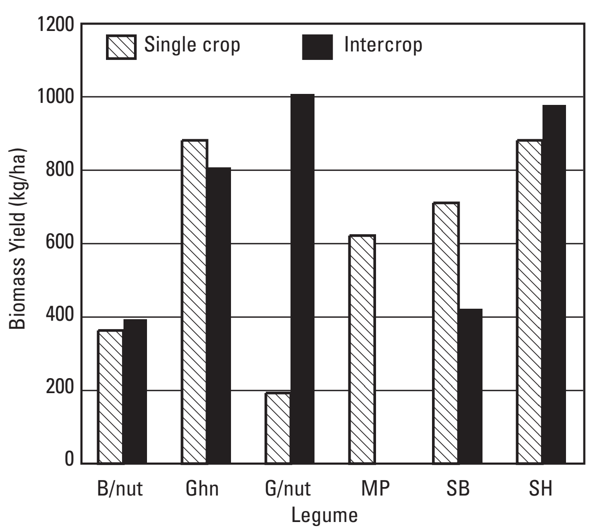


Figure 2. Rainfall in the Chikato area, 2000/2001 season.

Biomass yields. There were no differences in biomass yields between single crop and intercrop bambara (360 vs. 390 kg/ha) and grahamiana (880 vs. 890 kg/ha). Groundnut biomass yield was higher when intercropped than when grown as a single crop (1,010 kg/ha vs. 190 kg/ha). Soybean did better in a single crop system than when intercropped. Cowpea and pigeon pea biomass was not recorded from all of the farmers. The bunch cowpea matured early and it was not possible to record the amount of biomass, while the pigeon pea plants had fresh pods and farmers did not want to destroy them. Groundnut biomass yield from the intercrop was surprisingly high since it does not usually intercrop well. This high biomass could be the result of less moisture loss from maize during the long mid season dry spell.

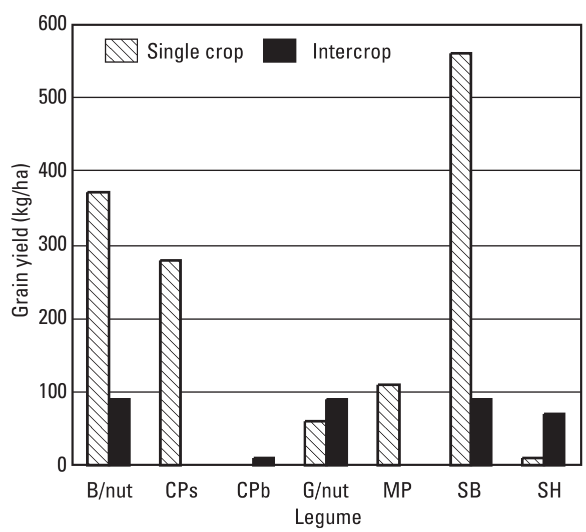
Grain yields. Grain yields from the single crop and intercropped legumes are compared in Figure 4. Bambara nut, spreading cowpea and soybean did well in a single crop system. Soybean was the highest yielding legume with 560 kg/ha of grain, followed by bambara nut with 370 kg/ha and spreading cowpea with 280 kg/ha. In the intercrop systems, bambara and soybean provided similar yields of 90 kg/ha, while cowpea yielded no grain. Yields of grahamiana and pigeon pea were not measured. Farmers harvested fresh pigeon pea for relish, making it difficult to measure the yields. An unknown larvae pest destroyed the pods of grahamiana.

Yield from intercropped maize. A comparison of the effects of intercropped legumes on maize yields is shown in Figure 5. Maize yield was highest in the grahamiana intercrop (2,430 kg/ha), followed by groundnut (1,750 kg/ha) and pigeon pea (890 kg/ha). The sunnhemp intercrop yielded no maize grain. The mucuna intercrop was used in comparing intercrop and single crop maize yields. The dry spell delayed planting of mucuna from six weeks after maize to when the maize was in the early stages of flowering. As a result, the mucuna started to spread when the maize had already matured. This provided a very minimal interaction effect, if any at all, and a zero effect line could be calculated from the maize yield of the mucuna intercrop yield as a control for comparison. It can be said that systems with maize yields above the zero effect line had a positive



Note: B/nut = Bambara; CPs = Spreading cowpea; CPb = Bunch cowpea; G/nut = Groundnut; MP = Mucuna; SB = Soybean; SH = Sunnhemp

Figure 3. Legume biomass yields.



Note: B/nut = Bambara; CPs = Spreading cowpea; CPb = Bunch cowpea; G/nut = Groundnut; MP = Mucuna; SB = Soybean; SH = Sunnhemp

Figure 4. Legume grain yields.

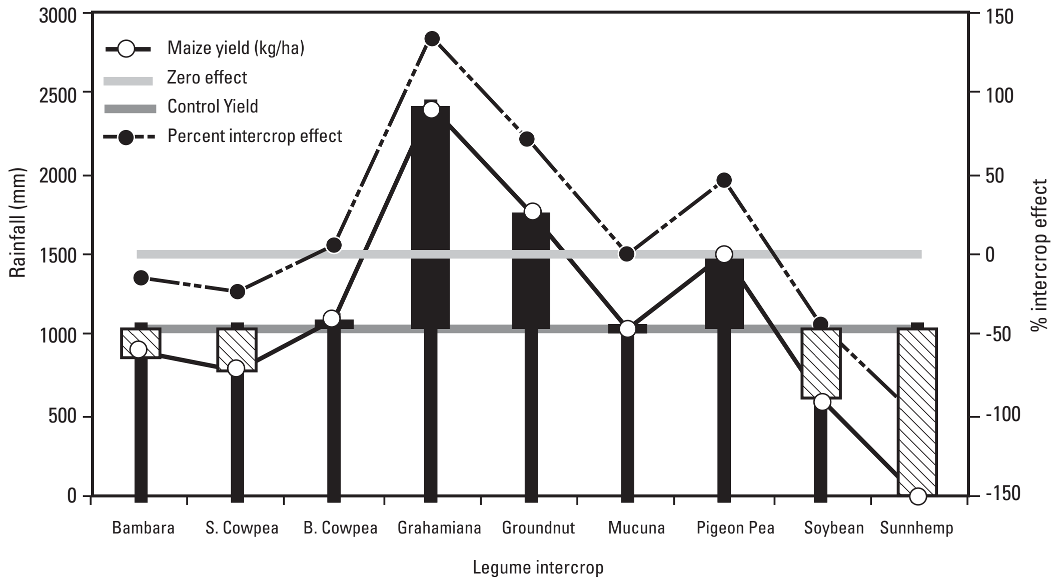


Figure 5. Maize yield and intercrop effect.

influence while systems with yields below this line negatively affected them. Grahamiana, pigeon pea and groundnut-based systems were found to have positively influenced maize yields while bambara, spreading cowpea, sunnhemp and soybean-based systems seemed to have a negative influence. The zero yield from sunnhemp suggests that the legume out-competed the maize crop.

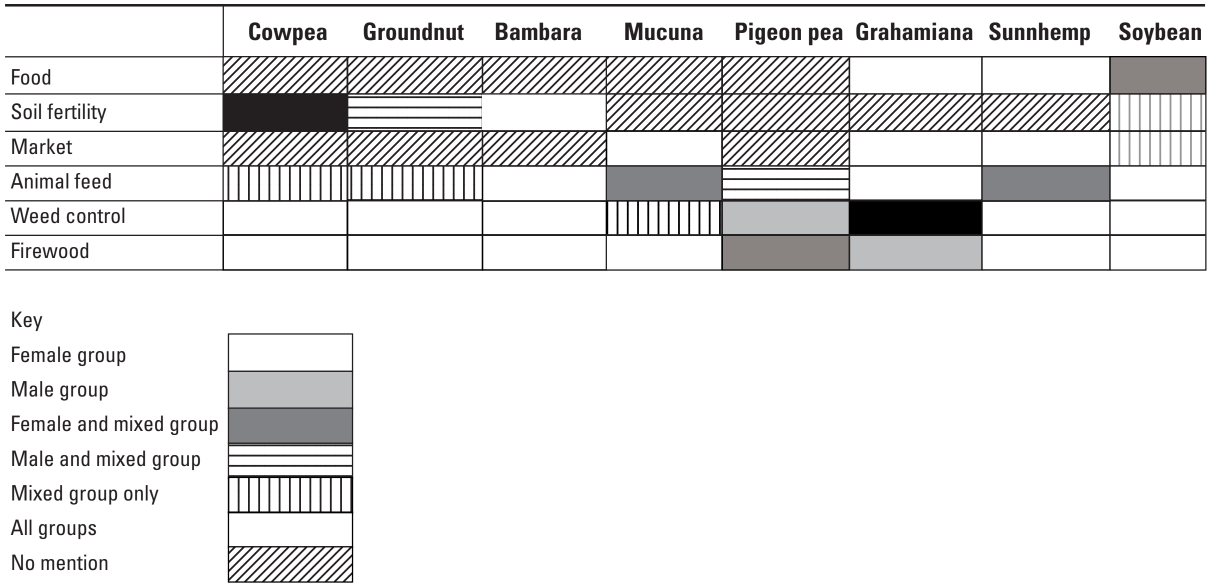
The percentage effect on yield reduction or increment is also shown in Figure 5. Yields increased by 150% in the grahamiana intercrop, 70% in the groundnut intercrop and 40% in the pigeon pea intercrop. The figures suggest that these legumes benefit the soil and crop during the same season and do not provide competition to the maize plant. One possible explanation could be that they provide a cover mulch effect that conserves moisture, especially during a dry spell. The yield trend also agrees with farmer observations that maize in the grahamiana and pigeon pea intercrops did not wilt much. There was no maize yield in the sunnhemp intercrop (a reduction of 100%) and about a 50% reduction in the soybean and spreading cowpea intercrops. Intercropping cowpea with maize is a common practice for most farmers in the area and few yield reductions were mentioned (Shumba 1990), but the yield reduction depends on plant population density. The relative density of intercropped cowpea in current practice is very small and any reduction in maize yield is negligible.

Farmer perceptions of legume uses

Farmers planted both traditional and introduced legumes in the trials. Traditional legumes were defined as those that farmers had been previously been planting and using while introduced legumes were defined as those that had been brought into the area by the CIMMYT Risk Project. Most farmers had not planted or used introduced legumes, although some of them had been planted by previous generations before being abandoned for various reasons. In addition to the familiar uses for established legumes, farmers identified different household and alternative uses for introduced legumes as shown in Table 4.

Traditional legumes were mainly grown for their food value. Cowpea and bean leaves are eaten as a vegetable relish while fresh; they are also boiled,

Table 4. Farmer perceptions of household and alternative uses of legumes by gender



dried and preserved for use in the dry season when green vegetables are scarce. While green and fresh, groundnut, pigeon pea, cowpea and bambara grains are boiled to make a protein-rich vegetable relish. The fresh green pods are also boiled and eaten as snacks. In addition, grains can be cooked as a relish when dry or ground to make *lupiza,* a thick paste also used as a relish. Groundnuts can be roasted, salted, and eaten as a snack, pounded to form traditional peanut butter, or pounded into a flour and used to season leaf vegetable relishes, porridges and other relish dishes. In addition to their food value, legumes provide opportunities for additional income at local markets; they can also be sold to the Grain Marketing Board if produced in abundance.

Farmers noted that, apart from food value and market opportunities, the legumes improved soil fertility. It had been from this knowledge that some farmers had systematically rotated legumes with maize to capitalize on the residual fertility. However, those legumes did not have a large impact on soil fertility because the varieties farmers grew did not produce much biomass or fix much N in the soil. The small scale and the practice of feeding residues directly to livestock after harvesting were also factors. Mucuna and grahamiana produced higher biomass than other legumes and farmers ranked these crops high in their potential to improve soil fertility.

Farmers also wanted to learn about the utilization of some legumes for uses other than soil fertility improvements, especially mucuna. Because of the L-dopa in mucuna, farmers were advised not to cook it until preparation lessons are conducted. Farmers thought mucuna could be used for coffee and suggested further exploration of this idea. A bean variety similar to mucuna is used in Malawi for coffee extraction.

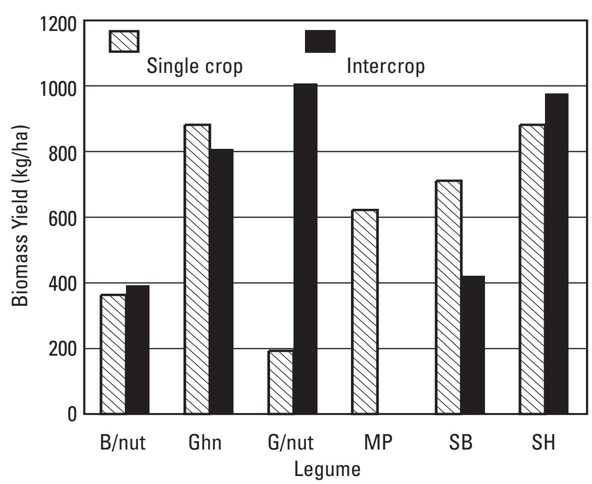
The farmers who harvested pigeon pea liked its taste and ease of preparation. For example, Mr. Chishere commented, "*Pigeon pea inonaka se beans uye haitri nguva yakawanda pamoto. Inogona kushandiswa se usavi….*" "The pigeon pea grain is sweet, just like beans, and it does not take time to cook. If it is cooked, you enjoy the food.…" In addition to food, some farmers used pigeon pea stems for firewood.

Farmers noted that another use for legumes such as pigeon pea, soybean and mucuna was as animal feed. It is also possible, though somewhat difficult, to extract milk from soybeans. Male farmers in particular said that the legumes would be fed to cows in order to boost milk production for consumption and sale. Goats were seen to like pigeon pea. Although commercial Brahman cattle ate mucuna, local cattle breeds did not. Farmers also observed reduced weed incidences in mucuna, grahamiana and sunnhemp plots. This reduction in weeds was particularly beneficial for the farmers, especially in helping to control the parasitic *Striga* weed that reduces maize yields.

Gender influence on farmer perceptions of legume uses. Gender played an important role in the values attached to each legume, and different farmer groups had different perceptions of legume uses. All groups ranked the legumes first by the role they played in food availability, and it is of note that grahamiana and sunnhemp were not mentioned as having any food value. Female farmers mentioned soybeans as being useful for food and indicated the constraints associated with its utilization. Introduced legumes were more highly valued for soil fertility improvements while traditional ones were primarily valued for food and market income. There was widespread agreement on the soil fertility improvements from mucuna, pigeon pea and grahamiana in all groups. The rankings of female farmers were more closely associated to uses that were directly linked to the household. For example, the female group mentioned firewood as a benefit from legumes whereas the male group did not. The above trends imply that those legumes that improve both soil fertility and grain yields have a high probability of being adopted and adapted by farmers.

Farmer ranking of legumes. Different crops have different uses, and Figure 6 shows the farmer ranking of legumes based on uses. Food and soil fertility were the main reasons farmers gave for growing the legumes, although there were differences within individual group rankings (Appendices 1-3). Farmers ranked each legume use and its importance to the welfare of the household as a whole. In the rankings, food, soil fertility, and market income seem to be of high importance across all crops. In addition, fuel wood was mentioned in two legume crops and weed control in three.

Perception of legume suitability by field type. Farmers evaluated the suitability of legumes for different field types after two years (Table 5). The homestead performed better than the topland fields in the four mother trials. Homesteads are generally suitable for most legumes because they are relatively fertile from manure and litter from household wastes. These fields were found to be best for all legumes except groundnut and bambara. Groundnut pods did not always fill in those homesteads that had received more manure. Farmers said that bambara does well in poor fields, and is thus best suited to the topland. In general, however, farmers observed that legumes had poor germination in abandoned fields. This was compounded by damage due to wild animals, although they did not affect mucuna and sunnhemp. Finally, low soil fertility also contributed to poor performance of the legumes. The performance of legumes on the topland clearly indicates that establishment of legumes in poor lands is difficult and may be expensive.



Note: B/nut = Bambara; CPs = Spreading cowpea; CPb = Bunch cowpea; G/nut = Groundnut; MP = Mucuna; SB = Soybean; SH = Sunnhemp

Figure 6. Farmer ranking of legumes by uses in Chikato.

In contrast, groundnut and pigeon pea grew well in the vlei and vlei margins. They are planted in August or September and harvested in December or January. The main constraint to legume production in the vlei is waterlogging. Pigeon pea does not perform well in waterlogged conditions (Nene 1990), but planting on ridges can reduce its effects. Mucuna and other legumes germinate but subsequently become yellow and stunted when waterlogged (Kumar Rao 1998). Growing legumes concurrently with maize would make it difficult to incorporate their biomass in the vlei, but other options may work if fast growing legumes such as sunnhemp are used.

Farmers similarly evaluated the legumes with respect to whether growing them in rotation was better than intercropping them (Table 6). Mucuna, sunnhemp and soybean were found to be highly competitive for resources, possibly killing the maize plants or reducing yields. Grahamiana, pigeon pea and groundnut were found to be well suited to intercrop as well as single crop systems.

Table 6. Legume suitability by system, as defined by farmers

Legume	Rotation	Intercropping
Mucuna	✓	X
Pigeon pea	✓	✓
Grahamiana	✓	✓
Sunnhemp	✓	X
Cowpea	X	✓
Soybean	✓	X
Bambara	✓	X
Groundnut	✓	✓

X - Legume does not suit the system
✓ - Legume suits the system

Table 5. Legume suitability by field type and season, as observed by farmers

		Field type			
Legume	Season	Vlei	Vlei margin	Homestead	Topland
Mucuna	Wet	X	X	✓✓	✓✓
	Dry	X	✓✓	✓	✓
	Avg	X	✓	✓✓	✓✓
Pigeon pea	Wet	X	X	✓	✓
	Dry	✓	✓✓	✓✓	✓
	Avg	X	✓✓	✓✓	✓
Grahamiana	Wet	X	✓	✓✓	✓
	Dry	X	✓	✓	✓
	Avg	X	X	✓✓	✓
Sunnhemp	Wet	X	X	✓✓	✓✓
	Dry	X	✓	✓✓	X
	Avg	X	X	✓✓	✓✓
Cowpea	Wet	X	X	✓✓	✓
	Dry	X	X	✓✓	✓
	Avg	X	X	✓✓	✓
Soybean	Wet	X	X	✓✓	✓
	Dry	✓	✓	✓	✓
	Avg	X	X	✓✓	✓
Groundnut	Wet	✓	✓	X	✓✓
	Dry	✓✓	X	X	X
	Avg	✓✓	X	✓	✓✓
Bambara	Wet	X	X	X	✓✓
	Dry	X	X	X	✓✓
	Avg	X	X	X	✓✓

Legend:
✓✓ - Legume best suited to land type
✓ - Legume suited to land type
X - Legume not suited to land type

Farmer perceptions of constraints and opportunities

The most important constraints identified by farmers were low soil fertility, diseases and pests, lack of adequate seed, market structure, lack of technical knowledge on management of legumes, the lack of food value, and the allocation of limited resources.

Farmers pointed out that the soils were very poor and that crops did not grow well without fertilizers or manure. The poor germination and performance of the first year were partly attributed to these factors. (In the second season, all legumes germinated well on soils with manure and Single Superphosphate fertilizer.) In the discussions, farmers said that growing a good legume crop would require planting on better land or applying manure. However, it would be difficult for a farmer to favor legumes over maize in the application of manure or the allocation of land. Farmers thus concluded that those legumes best suited to intercropping systems would be more compatible with their needs. In doing so, labor would be reduced and legumes would benefit from the manure or fertilizer applied to maize and from planting on prime land. Although some households may have sufficient resources to grow single crop legumes, those systems would suffer in households with more limited resources.

Diseases and pests were mentioned as the additional common constraint to legume production. Farmers observed that some soil-borne pests destroyed the seed of both legumes and maize before germination. Night attacks by wild animals also destroyed seeds and seedlings. Aphids were a problem for cowpea, groundnut and bambara plants in the dry spell. The aphid attack was so devastating that the bunch cowpea did not yield any grain in some farmers' fields. Farmers tried to control aphids by using Surf detergent, but it was ineffective. Farmers also did not know how to counteract the attack of boring insects, whose larvae laid eggs inside the pods and destroyed the fresh pigeon pea grain in both harvests. In general, pests are an extremely important constraint to production of cowpea, pigeon pea, and grahamiana, which experienced similar problems. Arrangements are underway to involve entomologists and pathologists in the project in order to investigate disease and pest attacks on the legumes.

Seed availability was widely mentioned as a big problem for adoption. For maximum soil benefits from legumes, biomass has to be incorporated into the soil (Bowen et al. 1988; Ikerra et al. 2000; Singh 1983). Evidence is conflicting, but Gilbert (1998), Kumwenda et al. (1997), and Chanika et al. (1999) reported that best responses for maize came when the legumes were incorporated at peak flowering. However, this practice leads to seed availability problems. Sakala et al. (2001) observed no difference in yield response between incorporating at flowering and incorporating after seed harvest. Farmers did not incorporate the legumes at flowering, as required by the project, because they wanted seed with which to expand planting of legumes in the next season. Sakala's observation, if borne out, would be a better fit with the wishes of farmers and the concept of sustainability.

Market issues were another constraint that farmers mentioned, especially for legumes such as mucuna. Although small production levels of traditional legumes did not worry farmers much, farmers needed to know whether they would be able to sell their product at market if they produced the seed in bulk. Adoption would be affected if markets were not identified for such legumes. Development of technology with farmers should therefore go along with identification of market opportunities. There is a need to empower farmers to create markets within their communities. For example, in Mangochi, Malawi, the soil fertility project implemented by ICRISAT taught farmers how to prepare mucuna for consumption. In the second season participating farmers started selling it in the local market as a snack. The market for mucuna was created and is still there in the area. Spreading information on how to prepare mucuna could likewise lead to the creation of markets for local consumption in Zimbabwe.

The lack of technical knowledge by farmers on legume management and utilization was also a constraint. Farmers might have heard of legumes such as mucuna, pigeon pea, sunnhemp, and grahamiana, but they had not seen them before. When these legumes were first introduced to them by the project, most farmers allocated them to poor soils because they were uncertain about the legumes and did not want to take unknown risks. Those farmers that took the risks associated with growing the legumes on their better fields had good yields, demonstrating the potential of the legumes. However, there was still minimal knowledge on management issues, such as proper time to plant in an intercrop, time to incorporate the legumes into the soil and on utilization such as preparation of mucuna seeds for consumption was still minimal. In the following seasons, experiments were designed and implemented to demonstrate on some of the technical issues.

In addition, legumes that provide food or other corollary benefits (such as animal feed) have a relatively higher potential of being adopted. Although legumes such as sunnhemp, grahamiana, and mucuna do not provide food value, grahamiana and mucuna have other values. Grahamiana grows well in a maize intercrop and produces a lot of leaf biomass for incorporation. Mucuna grows faster and produces a lot of leaf biomass for incorporation, as well as a lot of seed. Mucuna seed has food value, but it requires a very complicated and long preparation process before it can be consumed.

Allocation of limited resources was another constraint mentioned by some farmers. Legumes best suited to single crop systems would not be the best option for those with limited land, manure and labour. The priority in any season was to grow a food crop, in this case maize, on prime land with a large share of resources. Thus, legumes that would perform best in a single crop system would likely not be adopted by such households.

Discussion

Biological performance of legume systems

Biomass performance. The legumes that produced more biomass in intercrop also produced a better grain yield. As a general rule of thumb, only legumes producing above 2 t of biomass (about 60 kg N/ha) would be expected to provide a better yield response for maize the following year (Gilbert 1999; ICRISAT 2000). The biomass shown in the figures indicates that little impact should be observed next season. However, Buckles et al. (1998), in their study on mucuna in the hillside of northern Honduras, found that soil fertility improvements from the legumes were relative to biomass accumulation. There may be some variability in terms of impact since the yields shown are the average of the four mother fields.

Field type differences. Performance for individual fields in Zimuto was variable, with crops in the homestead fields performing better than those in the topland. Yield response for the following year may therefore be better in the homesteads than in the topland. The low biomass and grain yields were the result of water deficit stress experienced during the eight-week dry spell, which caused severe damage to the crops through moisture stress and diseases. Loehman et al (1994) observed similar effects of a dry spell in a study on measuring yield risk effects of new technologies in Cameroon. Nevertheless, the fact that legumes in the homestead fields performed better than those in the topland fields indicates that soil fertility is a key issue to consider in producing good legume crops. Poor performance of legumes on abandoned fields suggests that it is difficult and expensive to establish legumes in poor soils. The topland is less fertile, causing poor germination and minimal growth. This is exacerbated in some cases by shallow soil. Normal establishment of legumes would require boosting growth by applying inorganic fertilizer.

Maize yields. The results of maize yield in the intercropping systems showed that different legumes have different effects on yield. The plots in which maize yields were greater than the control plot indicated a compatibility between that legume and maize. For example, the grahamiana-maize intercrop not only had a high grahamiana biomass yield but also had the highest maize yields. Similarly, the pigeon pea and groundnut intercrop plots had better maize yields than other legumes. Despite good performance from the grahamiana-based system, farmers observed that pigeon pea and groundnut-based systems were more desirable because of the grain they harvested from these legumes. Finally, the total loss of maize yield in the sunnhemp intercrop implies that it likely has little chance of being adopted, as farmers will not intercrop it for its soil fertility benefits alone. Its fast growing characteristics cause it to cover and shade the maize easily. Its fast growing nature also means that the leaf biomass is ready for incorporation when the maize is still green (Gilbert 1999). The high biomass yield from sunnhemp suggests that the crop took advantage of the resources that were applied to maize. A yield of more than 2 t/ha would be necessary in the next season to offset the loss made by the competitive effect of sunnhemp the previous season and provide a net benefit.

Implications. The implications from these studies are numerous. First, legumes will not be adopted purely for soil fertility benefit. Farmers must perceive other, corollary benefits (Gilbert 1999), which include suitability in intercropping systems (Figure 6), additional grain yield for food (Low et al. 1991; Figure 4), weed suppression (Vissoh et al. 1998), and use of legumes for animal feed and fuelwood. Second, legume performance by field type may be a constraint to adoption, especially for resource poor farmers who cannot afford enough manure. Third, legumes could play an important role in diversifying farmers' cropping systems if they are well managed.

Perceptions of farmers on field performance of legumes

Agronomic and biometric evaluations of technologies, though useful, are no substitutes for farmer evaluation (Mutsaers et al. 1997). Statistical evaluation indicates relative performance of technologies based on a given set of conditions, but it does not explain the varied perceptions of farmers regarding the technologies (Mutsaers et al. 1997). What farmers perceive as positive in their condition reflects their socioeconomic status, making farmer evaluations the key to the success of any technology. The results of a one-year interaction with farmers indicates that their involvement in developing new technologies increased their demand for more legumes. In addition, gender played a role in the importance given to different uses of the legumes. While immediate needs such as food and fuelwood were highly emphasized by female farmers, emphasis among male farmers leaned towards animal feed. Although the trends were similar, individual group rankings of legumes and their uses vary somewhat (Appendices 1-3). A general overview of opportunities and constraints identified by farmers is listed in **Table** 7. Farmers ranked mucuna highly because of its high biomass in a single crop system, while grahamiana was found to be best for intercropping. Results shown in the figures agree with farmers' perceptions that mucuna performs better as a single crop and that grahamiana and pigeon pea are best for both intercrop and single crop systems. The results imply that planting maize together with either of these legumes could increase farm crop yields from a piece of land.

The wide range of constraints given in Table 7 indicates that establishing the legumes was not easy for farmers. In general, labor was not thought to be a big problem because draft animal power was used for plowing. However, more problems may exist in households with no draft power, especially in establishing the legumes in single crop systems. These households may not have the capacity to hire in labor for timely planting and weeding of legumes. Single crop legume systems therefore best fit those that have adequate resources, including land and potential labour. The ranking also implies that decisions about what legume to incorporate in the systems may depend on the influence of the head of the household (Fergusson 1994; Kolli and Bantilan 1997).

Table 7. Constraints and opportunities identified by farmers in Chikato

Legume	Constraints	Opportunities
Cowpea	- Aphid attack - Twine maize - Used Surf detergent but not effective	- Intercropping reduces aphids
Bambara	- No intercropping - Prone to striga (*Bise*)	- Rotation with rapoko
Groundnuts	- Aphid attack - Competes for planting labor with maize	- Intercropping reduces aphids - Market available
Mucuna	- Poisonous - Grows faster, kills maize, additional labor is needed - Dried seed difficult to open - No markets - Little knowledge - Seed availability	- Reduces weeds - More biomass - Pest resistant
Pigeon pea	- Seed availability - Pod diseases and pests - No proper growth on poor soils	- Animals like the crop - Suits intercropping
Grahamiana	- No food value - No market	- Suited to intercropping - Suppresses weeds
Sunnhemp	- No food value - No market - Little biomass - No intercropping - Requires manure	- Animals eat it
Soybean	- Requires manure - No intercropping - Little biomass at harvest - Seed availability	- Food value (home made soymilk and bread) - Market available - Soil fertility

Conclusions

The performance of legumes across field types has indicated that most legumes are suitable for homestead fields. Farmers’ evaluation of legumes showed a high interest in mucuna for a single crop system, and grahamiana or pigeon pea for intercropping systems. The legumes that provided high yields in the single and intercrop systems were also valued for their potential to improve soil fertility. The opportunities arising from the evaluation were the identification of legumes by field type, the need to improve planting depth, and new ideas about the utilization of legumes. The greatest challenges were noted to be diseases and pests (especially in pigeon pea and cowpea) and soil fertility. The issue of labor problems merits further research, as do the topics of improvements in intercropping to reduce yield reduction and the topic of legume utilization.

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Appendix 1

Mixed (male and female) group perceptions on legume uses.

Legume	Uses	Ranking
Cowpea	- Food	- 3.8
	- Markets	- 2.0
	- Animal feed	- 2.6
Groundnuts	- Food	- 3.7
	- Animal feed	- 3.4
	- Markets	- 2.4
	- Soil fertility	- 2.5
Bambara	- Food; *lupiza*, snack, relish	- 3.6
	- Market	- 2.9
Mucuna	- Could be used for food	- 1.6
	- Soil fertility	- 3.8
	- Observed animals eat leaf	- 1.0
	- Reduced weeds	- 3.8
Grahamiana	- Soil fertility	- 3.8
Sunnhemp	- Soil fertility	- 3.8
	- Feed animals	- 1.6
Pigeon pea	- Food	- 3.2
	- Soil fertility	- 3.0
	- Animal feed	- 3.6
	- Markets	- 1.0
Soybean	- Food; soybean milk, porridge	- 3.0
	- Markets	- 2.2
	- Soil fertility	- 2.0

Appendix 2

Male group perceptions on legume uses.

Legume	Uses	Ranking
Cowpea	- Food; leaf and grain vegetable, paste - Markets - Residues as feed	- 4 - 3.2 - 2.0
Groundnuts	- Food; relish, peanut butter, snack, seasoning - Animal feed - Markets	- 4.0 - 3.8 - 2.9
Bambara	- Food; lupiza, snack, relish - Markets	- 3.4 - 3.0
Mucuna	- Could be used for food - Soil fertility - Observed animals eat leaf - Weed suppression	- 1.4 - 4.0 - 1.2 - 3.6
Grahamiana	- Soil fertility - Firewood	- 3.8 - 1.0
Sunnhemp	- Soil fertility - Animal feed	- 1.6 - 1.2
Pigeon pea	- Food; fresh grain, snack, relish - Soil fertility - Animal feed - Markets - Fuel wood	- 3.8 - 3.4 - 3.5 - 1.7 - 1.0
Soybean	- Food; soybean milk, porridge - Markets - Soil fertility	- 3.9 - 1.3 - 2.8

Appendix 3

Female group perceptions on legume use.

Legume	Uses	Ranking
Cowpea	- Leaves as vegetable relish, pods as relish and snack, grain cooked, mixed with maize kernels - Sell	- 3.9 - 2.4
Bambara	- Food - Sell	- 3.7 - 3.0
Groundnut	- Residues for manure - Food - Sell - Animal feed	- 2.0 - 3.6 - 2.4 - 2.8
Mucuna	- Green manure - Animal feed - Food - Weed suppression	- 3.8 - 1.0 - 1.2 - 2.9
Grahamiana	- Soil fertility - Weed suppression - Fuel wood	- 3.6 - 2.4 - 1.4
Sunnhemp	- Soil fertility	- 2.6
Soybean	- Food	- 3.0
Pigeon pea	- Food - Animal feed - Soil fertility - Fuel wood	- 3.4 - 2.8 - 3.0 - 1.6