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Full Length Research Paper

Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi

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Maize (*Zea mays* L.) is a major staple food in Malawi. However, low soil fertility resulting from low and inappropriate use of fertilizer practices, continuous monocropping and inappropriate crop residues management coupled with limited resources and droughts keep yields low. This had led to a quest for sustainable solutions such as maize-legume intercropping or rotation including more efficient use of crop residues in smallholder farming systems. Innovation platforms (IP) built around learning centres (LC) located on smallholder farmers' fields in target locations were used as an approach to disseminate integrated soil fertility management (ISFM) technologies and build capacity of farmers, extension staff and other stakeholders. Rotating maize with either groundnut or groundnut intercropped with pigeonpea increased maize grain yield (3678 and 3071 kg ha^{-1} respectively) compared to sole maize (2260 kg ha^{-1}). These preliminary findings were linked to farmer assessment of technologies where farmers participating in the LCs expressed strong interest in the maize legume rotation technologies. Associated farmer field days outlined constraints underlying technology choice, information that is not usually considered in conjunction with on-farm experimentation. Although, the legumes were highly productive, farmers expressed worries about legume seed availability, disease incidences, weeds infestations and livestock damage. Participating farmers commonly manage residues by burning. Promotion and experimentation with more efficient use of legume residues have shown short-term positive impacts in efforts to promote scaling-out of best fit legume technologies. This study reports the value of multi-stakeholder partnering in scaling-out and evaluation of best fit legume technologies and adoption constraints.

Key words: Maize, integrated soil fertility management, innovation platforms, learning centres, legume technologies.

INTRODUCTION

Maize remains the most important food crop for Malawi, occupying 70 to 85% of the land area under cultivation (Smale et al., 1991). The remaining of smallholder arable land is sown to tobacco (*Nicotiana tabacum*), cotton (*Gossypium hirsutum*), groundnut (*Arachis hypogea*), common bean (*Phaseolus vulgaris*), pigeonpea (*Cajanus cajan*) and other crops. Resource poor smallholder farmers in Malawi are limited to one crop per season due to unimodal pattern of precipitation. Planting starts around November and harvest is in April to May with the exception of long-duration pigeonpea, which is harvested 2 to 4 months later. Although, potential yields on farmers'

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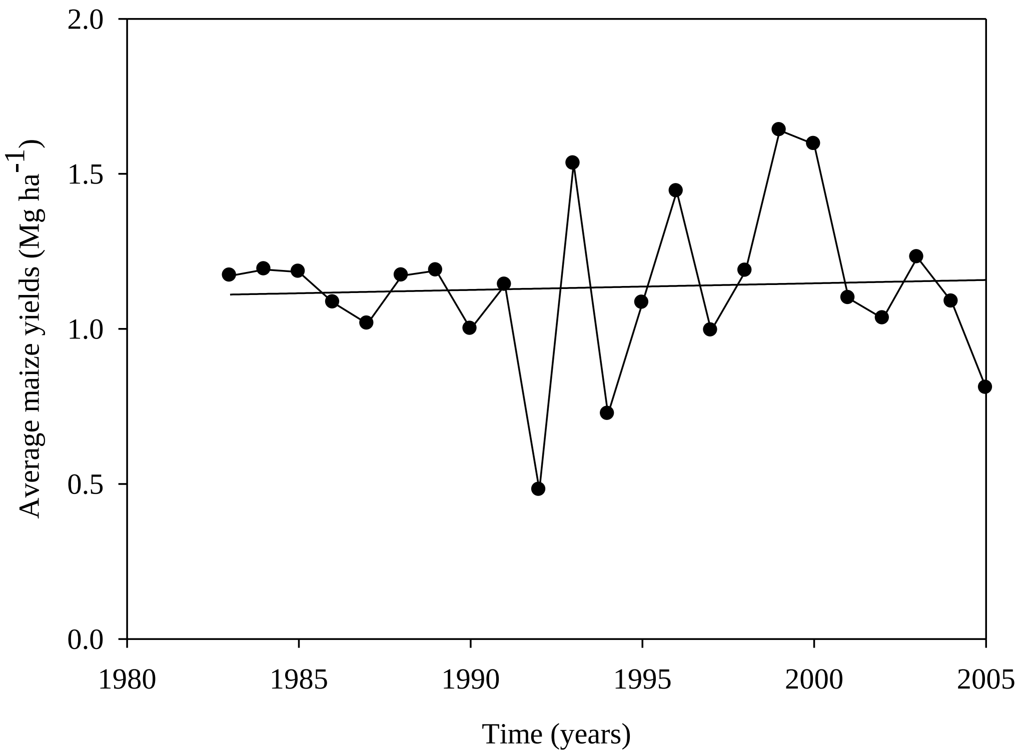

Figure 1. Average maize yields (mg ha^{-1}) in Malawi from 1982-2008 (MoAFS, 2008).

fields are 6 to 7 mg ha^{-1} (MoAFS, 2005), yields on farmers' fields are low (Kumwenda, 1998). Over the last 25 years, average maize yields in Malawi remained low around 1.1 mg ha^{-1} until 2005 (Figure 1). Average maize yields were more stable between 1982 and 1991 and were more variable between 1992 and 2004 due to the adoption of structural adjustment programs instituted by the World Bank and International Monetary Fund (Chilowa, 1998), droughts (1997 to 993, 1994 to 1995, 2004 to 2005) despite the small-scale distribution of free maize seed and fertilizer matching, 0.1 ha to most vulnerable households (1997 to 2004). Average maize yields have jumped from approximately 1.1 mg ha^{-1} in the 2004/2005 season to 1.6 mg ha^{-1} in the 2005/2006 season. This was due to re-introduction of large-scale (heavily subsidized maize seed and fertilizer matching 0.4 ha) farm input subsidy programme (FISP) by the Malawi Government in defiance of the international community and IMF disapproval of input subsidies.

In the subsequent seasons estimated average maize yields were 2.6 (2006/2007), 1.6 (2007/2008), 1.7 (2008/2009), 1.8 (2009/2010) and 2.1 mg ha^{-1} (2010/2011), respectively (Denning et al., 2009; MoAFS, 2011). However, even with subsidized inputs; the gap between actual and potential yield is still very wide. The payoffs to such investments can be increased through the pursuit of greater resource use efficiency with the realization that solutions to maintenance and improvement of soil fertility cannot be solely through use of inorganic fertilizers. Declining soil fertility has been regarded as the main cause for low maize productivity in Malawi (Zambezi et al., 1993; Kumwenda et al., 1997; ICRISAT/MAI, 2000; Blackie and Mann, 2005; MoAIFS, 2005). For example, phosphorus levels range from sufficient to low with widespread deficiencies in nitrogen and organic carbon ranging from 0.8 to 1.5% on Malawian smallholders fields (Snapp, 1998). This has come about due to continuous cropping as a result of increasing land pressure with most farmers sowing an average area of land of less than 2 ha (Cronwell and Winpenny, 1993), and the declining use of farm inputs such as fertilizers and improved seed due to high cost. Purchases fell because of a reduction in the availability of farm credit and a sharp increase in fertilizer prices, to unprecedented 14 times the price of grain between mid 1980s and 1990s (Benson, 1997). In addition, manure is generally in short supply especially that as over 12.5 ton/ha needs to be applied each year to maintain soil organic matter: this would require 20 full grown cattle for each hectare of crops.

Most smallholder farmers grow maize after maize every year implying removal of the same nutrients year after year. Moreover, most farmers do not return most of the crop residues to their fields despite this being one of the key extension messages (Snapp et al., 2002b). Promotion and experimentation with more efficient use of legume residues may offer higher short-term impacts. To revert the problem of low soil fertility, a lot of work has been done on screening green manures, intercropping and crop rotation systems and inorganic and green manure fertilizer combinations. Building on green manure research conducted early in the 1900's (Blackshaw, 1921; Brown, 1958) experimentation in the past 20 years has targeted agroforestry systems (*Leucaena* hedgerows with maize, or relay intercrops of maize with *Sesbania sesban*), green manures (for example maize/mucuna, maize/crotalaria and maize/lablab rotations) and grain legume intercropping or rotations (MacColl, 1989; Banda et al., 1994; Kumwenda and Benson, 1998; Kumwenda et al., 1998; ICRISAT/MAI, 2000; Sakala et al., 2003; Sakala and Kabambe, 2004; MoAFS, 2005; Myaka et al., 2006; Mhango, 2011). Out of all these, food legumes are more preferred (Bezner-Kerr et al., 2007; Mhango, 2011) by smallholder farmers because they are a source of plant proteins and income and this has implications on potential of legumes to build soil fertility. Work conducted by Maize Productivity Task Force showed that legumes such as groundnuts, soybeans could yield higher than continuous unfertilized maize under low nutrient soils (Gilbert et al., 2002). Integration of grain legumes such as groundnuts, soybean, cowpeas and bambara groundnut in maize legume rotation systems can increase yield of maize because legumes improve soil fertility through biological nitrogen fixation and residue incorporation (Snapp, 1998; Nhamo et al., 2003; Mhango et al., 2008; Nyemba and Dakora, 2010).

Rowe and Giller (2003), Ojiem et al. (2007), Nyemba and Dakora (2010) and Mhango (2011) reported biological N fixation of 33 to 124 kg ha^{-1} by groundnut while Chikowo et al. (2004), Adu-Gyamfi et al. (2007) and Egbe et al. (2007) reported biological N fixation of 20 to 118 kg ha^{-1} by pigeonpea. Yield benefits ranging from 30 to 60% have been reported where legume based manures have been used depending on their quantity, quality and timing of application. Combined use of organic and inorganic fertilizers gives better yields because of improvement of both the soil physical and chemical properties (Mwato et al., 1999). Other benefits from a well planned crop rotation include improved soil water management, reduction of soil erosion, reduced insects and disease problems and improved soil aggregate stability. Legumes have long been advocated as the missing ingredient for conserving soil resources in subsistence agriculture (Cronmwell and Winpenny, 1993). A reconnaissance survey found that Malawian farmers were experimenting with the application of low fertilizer rates, a wide range of new crops and the incorporation of crop residues (Rohrback and Snapp, 1997). Despite having a basket of options for the soil fertility technologies, adoption rate is low and farmers still get low yields even in a year with favourable rainfall distribution as evidenced by food insecurity problems in most households (Kanyama-Phiri et al., 2000). The adoption rates for 'best-bet' legume technologies appear likely to remain low unless seed markets are improved (Snapp, 2002). The main requirement in order to scale out the maize legume cropping systems approach is sufficient supply of high quality legume seeds (Myaka et al., 2006). Most non-governmental organizations (NGOs) operating in Malawi advocate crop diversification as a strategy to improve the livelihoods of poor households using pass-on seed systems. In order to accelerate agricultural technology adaptation, many countries in Sub-Saharan African including Malawi have embraced a systems approach to Agricultural Research and Development (Anandajayasekeram, 2005).

The use of innovation platforms (IP's) in Agricultural Research and Development is further use of a systems approach that embraces all relevant players in the value chain for an innovation by shedding light and facilitating, where possible, on the roles and responsibilities; actions and interactions; and norms and values that condition behaviour and actions. Innovation platforms represent a significant change from the conventional linear perspectives on technological change by emphasizing the importance of studying an 'innovation' as a single unit comprising actors involved. An innovation is defined by the Webster's Ninth New Collegiate Dictionary as 'an introduction of something' or 'a new idea, method or device'. For this study, the term innovation included not only the adoption of grain legumes by farmers, but also a range of other processes such as reorganization of interactions by a group of actors in the value chain, reorganization of farmers in seed sharing strategies, the use of new learning and teaching method by extension workers and changes in farm management by farmers among others. Innovation actors included public sector entities (Bunda College, Chitedze Research, Department of Agricultural Extension Services); private sector actors that is NGOs (CARE Malawi and World Vision International) and farmers and farmer groups. The key commodity linking these actors was information. The major objective of the study was to experiment the use of IP's to disseminate ISFM technology to stakeholders (farmers, extension service providers, local leaders, researchers and agro-input dealers) while at the same time building their capacities.

The main objective of the studies in this report was therefore to pilot a process of packaging and evaluating grain legume based cropping systems for improved crop productivity amongst small holder farmers in central Malawi. The specific objective was to evaluate the use of innovation platforms at different levels (from decision making technocrats to farm communities) to develop and test technological innovations in order to accelerate adoption.

MATERIALS AND METHODS

Study approach

The main working concept in the studies was to initiate a two way communication mechanism amongst researchers, extensions agents and farmers in which constraints to ISFM practices are

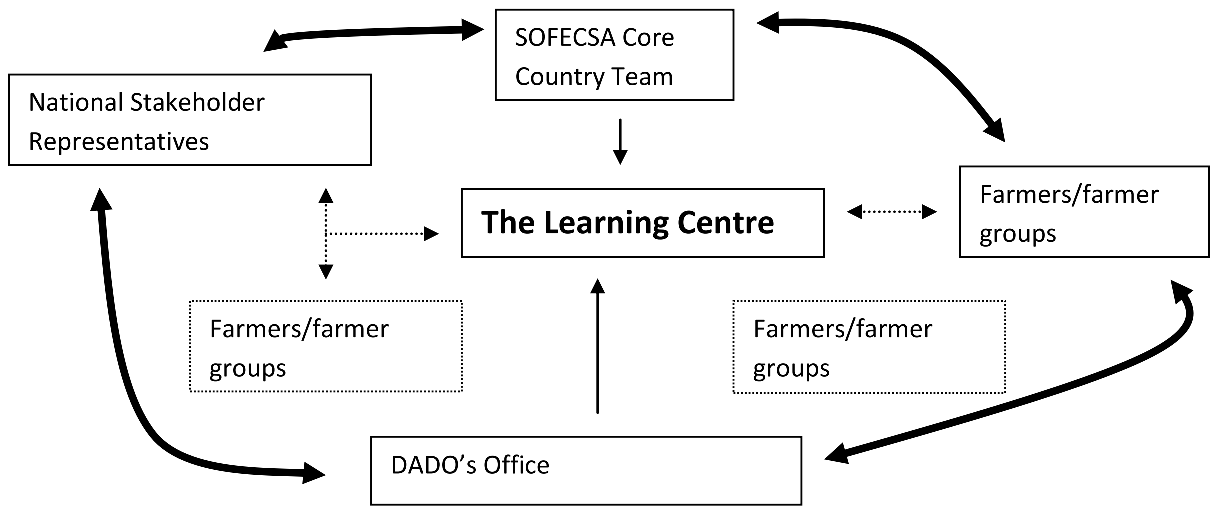

Figure 2. Schematic representation of innovation platform used in scaling out best fit legumes for soil fertility enhancement in smallholder farming systems.

Table 1. Physical and chemical characteristics of soils collected from learning centers located on farmers' fields in four EPAs under study in November, 2006.

Site	Sand (%)	Clay (%)	Organic carbon (%)	Total N (%)	Available P (ppm)	pH (H_2O)
Mpingu (n = 9)	50.7 (3.8)	24.8 (3.2)	0.89 (0.08)	0.19 (0.006)	7.08(2.32)	4.6 (0.08)
Mulonyeni (n = 9)	43.7 (3.9)	34.1 (2.5)	0.59 (0.11)	0.18 (0.007)	12.50 (4.45)	4.6 (0.09)
Chiwosya (n = 9)	51.9 (4.0)	30.4 (1.3)	0.65 (0.13)	0.16 (0.005)	26.5 (6.72)	4.9 (0.09)
Mulonyeni (WVI) (n = 3)	51.7 (4.9)	32.3 (1.6)	0.55 (0.22)	0.15 (0.012)	33.2 (11.04)	4.8 (0.15)
Mkwinda (n = 8)	43.3 (3.8)	30.6 (3.9)	1.2 (0.16)	0.2 (0.008)	13.6 (5.41)	5.3 (0.14)

Figures in brackets indicate standard errors.

identified and best-fit options/solutions identified and supported for scaling out. Innovation platform (IP) approaches were used which brought representatives of the three groups together. The soil fertility consortium (SOFECSA) facilitated the operationisation of the IP and resultant field demonstrations plots, hereafter called learning centres, training and other activities described here under. IP partnership enabled cost sharing for improved effectiveness.

Innovation platforms

The initial bringing together of the national representatives was initiated by the SOFECSA Core Country Team. The SOFECSA Core Country Team managed all the activities (Figure 1) in support of the National Stakeholder Representatives who decided what best fit legumes to be included in the learning centres (LC's) at national level while incorporating farmers' feedback. At the centre of all this was the LC where all stakeholders converged and interacted. District Agriculture Development Office (DADO) was responsible for the management of the LC assisted by 'agricultural extension workers' and NGO staff in representative EPAs.

Study sites

Five study sites selected were Mkwinda, Malingunde, and Mpingu Extension Planning Areas (EPAs) in Lilongwe district in Lilongwe Agricultural Development Division (ADD) and Mulonyeni and Chiwosya in Mchinji district in Kasungu ADD. All the sites were in central region of Malawi and were similar in terms of a range of common crops grown and low fertilizer use in maize but differed in terms of groundnut crop use. All the areas fall under mid-altitude with unimodal rainfall pattern (800 to 1200 mm) with onset in October or November. Rainfall was recorded at a central point in each EPA (Figure 2). Composite soil samples were taken from 0 to 20 cm depth from all learning centres on trial site basis and plot by plot basis at the end of the first and second season respectively. In terms of pH, the results show that most soils had pH of below 5.0 except at Mkwinda where it was above 5.0 implying they would require some soil amendments such as liming for better crop performance (Table 1). Many soils were low in inorganic P compared to a minimum threshold of 25 ppm for Malawian soils. Both organic carbon and nitrogen contents were very low to maintain good soil structure.

Surprisingly, clay content of most soils was high providing room for soil organic matter and soil structure improvement if proper residue management was followed (Figure 3).

IP identification of learning centre (LC) treatments

We were working with Non Governmental Organizations (NGOs) and extension workers to scale out best fit legume technologies using LC's located on farmers' fields. NGOs wanted to work with us to get technical support in their efforts to advocate crop

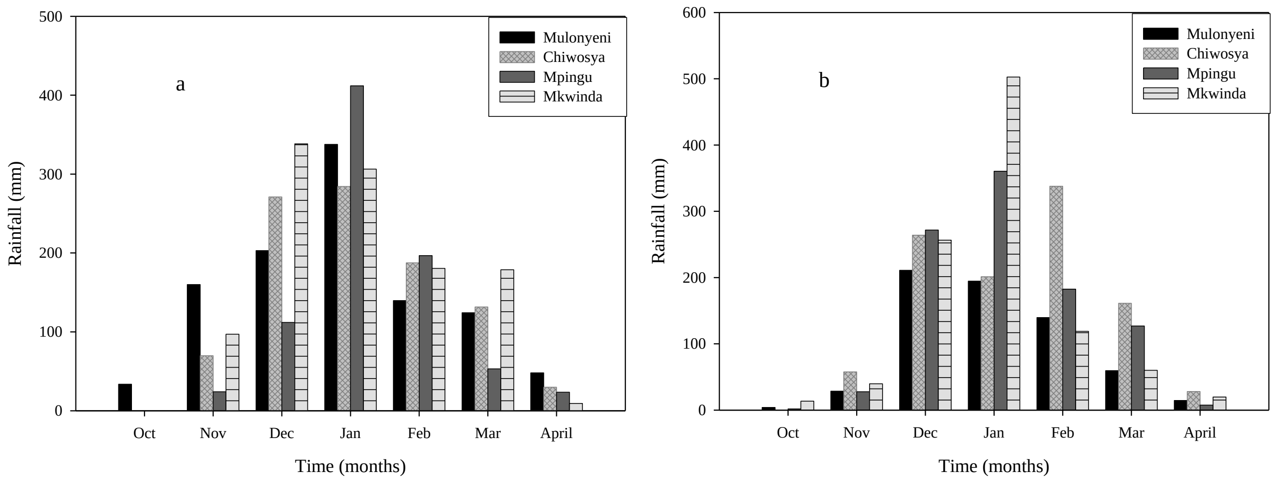

Figure 3. Rainfall pattern in four EPAs of Central Malawi where learning centres were located in farmers' fields for 2006/07(a) and 2007/2008 (b) cropping seasons.

Table 2. Distribution of learning centres by EPA for 2006/2007 and 2007/2008.

Location	No. of farmers '2006/2007	No. of farmers '2007/2008	Partners
Mchinji:- Mulonyeni EPA Kalumbe area	10	8	Extension, Chitedze Research Station.
Mulonyeni Tembwe area (WVI)	10	5	WVI, Chitedze Research Station.
Chiwosya EPA	11	9	Extension, Chitedze Research Station.
Mpingu EPA	12	7	Extension, Chitedze Research Station.
Mkwinda	8	8	Extension Dpt, Bunda College.
Malingunde	8	5	CARE, Chitedze Research Station.

diversification. A total of 59 farmers were selected to participate in the study. Farmer selection was conducted by NGOs and extension staff using the following criteria: i) size of landholding (large, medium and small as a relative measure used at group meetings with local farmers by our partners); ii) gender (male as well as female farmers). These helped to achieve the highest possible degree of representation within each learning centre. The selected farmers had to be willing to collaborate with researchers, NGOs and the extension workers, and their plots were also located close to roads for passers- by to see. The LC's were maintained on the same plots for two consecutive growing seasons to complete two year rotation system. Some farmers abandoned the project over the two cropping seasons, leaving only 42 farmers for the final harvest in 2008 (Table 2). The main factors that caused the farmers to leave the learning centres were changes in land ownership or health problems.

The roles of various stakeholders in the innovation platform of scaling out best fit legumes technologies using learning centres are shown in Table 3.

Treatments, plots sizes and trial management

In 2006/2007 season, farmers planted four plots comprising a pure maize crop with fertilizer, pure maize stand without fertilizer and two of the following three treatments: pure stand of groundnuts, maize and pigeonpea intercrop and groundnut and pigeonpea intercrop. Groundnut and pigeonpea varieties used in trials were CG7 and ICEAP 00040 respectively while maize variety used was DKC8073. When selecting the variety, the local conditions were taken into consideration. In 2007/2008, all plots were planted with fertilized maize using lower than the recommended fertilizer application rate for the areas under study (46:21:0:4S). It was therefore hypothesized that the residue N contributions would top up the N in the systems to the recommended 69 kg/ha or more. A complete description of treatments is shown in Table 4. Plots comprised of 15 ridges, 15 m long. Ridge spacing was 75 cm for all treatments. The spacing for maize was 25 cm × 1 seeds/station. Basal and top dressing fertilizer was applied to maize providing 46:21:0 + 4S from 23:21:0 + 4S and urea.

Farmer and collaborators training

Training was conducted for participating staff and farmers at Mkwinda, Chiwosya and Mpingu EPAs. The training was conducted in local language. However, training material was written in English and translated in Chichewa. Farmers were trained on principles of agronomic management so that they can benefit from the systems. This highlighted importance of correct variety choice, correct spacing and population, timely planting, fertilizer application, and weeding on crop yield and pest and disease escape. Farmers appreciated this workshop and shared their experiences of success. The importance of proper legume seed storage and legume rotations was presented, emphasizing the aspects of nematode control for legumes and witchweed control for maize.

Table 3. Active involvement of various stakeholders in the innovation platform of scaling out best fit legumes technologies using learning centres located on farmers' fields.

Partners	Roles	Contributions
NGO's such as CARE and World Vision	Management of learning centres. Farmer Identification. Training of farmers.	Human resource. Management of learning centres. Data collection in learning centres.
Extension Department	Same as NGO's, more important where NGO's not available.	Same as NGO's. Some cost sharing on transport.
Chitedze Research Station (coordinating unit)	Coordination of activities. Supervisory visits. Trial design, analysis and reporting. Packaging trial inputs. Operational management.	Human resource. Management of trials. Data collection in learning centres.
Farmers	Provide feedback. Data collection in the baby trials. Dissemination of information about varieties suitable to the area.	Provide resources like land and labor for learning centres management.
Bunda College	Technical backstopping, coordination, fostering IP interactions.	Human resources. Soil lab analysis.
LRCD	Fostering and coordination of IP and building support at grass root extension.	Human resource.

Table 4. Treatments for learning centres in 2006/2007 and 2007/2008 seasons.

Treatment description 2006/2007	Treatment description 2007/2008
Maize with 69:21:0+4S fertilizer	Half rate of nitrogen fertilizer (46:21:0:4S)
Maize without fertilizer	Half rate of nitrogen fertilizer (46:21:0:4S)
Maize with 69:21:0+4S plus pigeonpea intercrop	Half rate of nitrogen fertilizer (46:21:0:4S)
Groundnut and pigeonpea intercropping	Half rate of nitrogen fertilizer (46:21:0:4S)
Groundnut alone	Half rate of nitrogen fertilizer (46:21:0:4S)

RESULTS

First season (2006/2007) results of maize and groundnut grain yield in intercrop with pigeonpea

An analysis of the results gave significant maize differences amongst the maize treatments. As expected at all study sites, fertilized maize gave significantly higher maize yields ($p<0.01$) than unfertilized maize (Table 5). Intercropping maize with pigeonpea significantly reduced maize yields ($p<0.001$) only at Mkwinda while at other sites yield reduction was not significant. In terms of sites, Chiwosya gave highest maize yields (2.8 mg ha^{-1}) followed by Mkwinda (2.2 mg ha^{-1}) with lowest yields obtained from Mulonyeni (1 mg ha^{-1}). Results from this season are important to note because this was a good rainfall year and water stress should have been much less. Yield of groundnut was recorded from 29 farmers. Lowest average groundnut yields (0.44 mg ha^{-1}) were recorded in Mulonyeni which has very sandy soils, while highest average yields (0.75 mg ha$^{-1)}$ were at Mpingu (Table 6). The groundnut crop performed generally well during the season. The potential yields for groundnut are 1.5 to 2 mg ha^{-1}. However, yields of 1 mg ha^{-1} are considered good.

Results of maize grain yields in sole and rotation with grain legumes (second season, 2007/2008)

Smallholder farmers require technologies that perform in the near-term as well as over the long-term, so here the

Table 5. Yield of maize, mg ha^{-1}, at Chiwosya, Mulonyeni, Mpingu and Mkwinda EPAs for 2006/2007 cropping season.

Treatment 2006/2007	Chiwosya	Mulonyeni	Mpingu	Mkwinda
Maize + 0 Fertilizer	1.30^{b}	0.75^{b}	1.13^{b}	1.46^{b}
Maize + 69:21:0+4S	3.39^{a}	2.55^{a}	2.86^{a}	3.14^{a}
Maize +PP+ 69:21:0+4S	3.71^{a}	2.50^{a}	2.32^{a}	1.89^{b}
Mean	2.80	1.93	2.11	2.16
P	0.01	0.003	0.015	<0.001
LSD (0.05)	1.76	0.99	1.14	0.59
CV (%)	39.8	45.9	48.3	23.9

Means followed by the same letter are not significantly different at 5% (LSD). PP = pigeonpea.

Table 6. Yield of groundnut (mg ha^{-1}) from first season of rotation system at various EPAs.

EPA	Treatment '2006/2007	Mean G/nut yield (kg/ha)	Range
Chiwosya	Groundnut	0.61	0.19-1.17
Chiwosya	G/nut-PP intercrop	0.72	0.61-0.89
Malingunde	Groundnut	0.70	0.43-0.96
Mkwinda	Groundnut	-	-
Mpingu	Groundnut	0.75	0.15-1.79
Mulonyeni	Groundnut	0.49	0.44-0.53
Mulonyeni WVI	Groundnut	0.53	0.08-1.01

G/nut = groundnut; PP = pigeonpea.

Table 7. Yield of maize (mg ha^{-1}) in sole and rotation with grain legumes at various EPAs for 2007/2008 cropping season.

Treatments 2006/2007	Treatments 2007/2008	Chiwosya	Mulonyeni	Mpingu	Mkwinda
Maize + No Fert	Maize + 46:21:0:4S	2.23^{b}	2.22^{b}	2.09^{b}	3.03^{c}
Maize + 69:21:0:4S	Maize + 46:21:0:4S	3.22^{ab}	3.03^{a}	3.08^{a}	3.42^{bc}
Maize + 69:21:0:4S + PP	Maize + 46:21:0:4S	3.75^{a}	3.09^{a}	3.19^{a}	4.14^{ab}
G/nut alone	Maize + 46:21:0:4S	3.93^{a}	3.24^{a}	3.85^{a}	4.85^{a}
	Mean	3.28	2.89	3.05	3.86
	P	0.02	0.003	0.011	0.039
	LSD (0.05)	1.04	0.54	0.93	1.09
	CV (%)	19.9	21.7	28.4	8.8

Means followed by the same letter are not significantly different at 5% (LSD). G/nut = groundnut; PP = pigeonpea.

report covers initial biological performance and farmer evaluation. The data from five sites presented here can only estimate the potential for multi-year soil fertility benefits. An analysis of the trial treatments results gave significant maize differences amongst the maize treatments. Fertilized maize planted after unfertilized maize was significantly lower (p<0.001) than all the other four treatments (Table 7). Maize planted after groundnut gave the highest yield (3.6 t ha^{-1}) followed by maize planted after fertilized maize intercropped with pigeonpea (3.3 t ha^{-1}). This is in contrast to what was observed last season where intercropped maize gave lower yields than pure stand. These results suggest that benefits of intercropping maize with pigeonpea can be realized the following season where a farmer plants maize in pure stand after maize and pigeonpea intercrop. Also, fertilized maize yields during the 2007/2008 cropping season were relatively higher than what was recorded last cropping season. For example this season fertilized maize registered yield of 3.2 t ha^{-1} against yield of 2.9 tha^{-1} recorded last season but with higher rate of N fertilization (69:21:0:4S) against a superimposed N fertilization of 46:21:0:4S per ha. Both seasons were noted good seasons because of good rainfall pattern suggesting that soil moisture stress could have been minimal at critical crop growth.

Table 8. Farmers' perception, as percentage on various attributes of treatments at Mpingu, Chioshya and Mulonyeni EPAs during field days.

Assessment criteria	EPA and number of field day participants (in brackets)		
	Mpingu (75)	Chioshya (17)	Mulonyeni (15)
Maize seed cost	80	94	100
Maize seed access	94	84	100
Fertilizer cost	70	58	80
Fertilizer access	67	18	66
Groundnut seed access	69	-	93
Pigeonpea seed access	33	-	66
Groundnut crop choice	52	64	93
Pigeonpea crop choice	27	82	80
suitability for home use –maize	100	94	93
suitability home use –groundnut	100	94	93
suitability for home use –pigeonpea	60	76	80
Suitability for cash - maize	60	47	66
Suitability for cash - groundnut	81	94	100
Suitability for cash - pigeonpea	80	88	93

Farmer evaluation of technologies

The preference rating of technology options by farmers participating in the learning centres was also consistent across sites. Average ratings, on a scale of 1 (very low) to 4 (very high) were as follows (S.D. in parentheses): sole maize = 3.0 (1.1); maize-pigeonpea intercropping = 2.5 (1.0); groundnut-pigeonpea intercropping = 1.6 (1.2); groundnut-maize rotation = 1.3 (1.0) and sole pigeonpea = 1.0 (0.8). Farmers seem to be expressing interest in legume intensification. A different picture seems to emerge, however, when farmers are asked to explain their views of the positive and negative traits characterizing these technologies. More than three quarters of the farmers mentioned soil fertility enhancement as one of the benefits of best fit legume technologies apart from consumed as relish (Table 8). However, farmers participating in the learning centres raised concerns on the problems of certified legume seed availability, insect pests, weeds infestation and livestock damage. Most participating farmers raised concerns about the availability of certified legume seed. Lack of access to groundnut seed was most frequently noted, though pigeonpea was also noted as being expensive and unavailable. Rosette disease and infestation by the parasitic weed *Alectra vogelii* mostly affected the performance of groundnut crop particularly in Mkwinda EPA prompting farmers to rank sole groundnut crop lowly. At all EPA's harvest field days were conducted and responses were sought from participants on various issues expressed as percentages of people expressing positive attributes to a specific criterion (Table 8).

In general, participants showed that accessing or affording maize seed was much easier than fertilizer. This is expected, as larger quantities are needed, and also, fertilizer is an imported commodity in Malawi. At all EPA's farmers were happier with the choice of groundnut rather groundnut. Groundnuts were rated highly as a cash crop and for home use. Pigeonpeas were less preferred for home use and for cash generation. However, there was variation in terms of fertilizer cost, fertilizer access and pigeonpea seed access among sites.

DISCUSSION

Acceptance of legume rotation, role of innovation platforms

Historically, technologies to improve maize productivity of nutrient-low soils have depended heavily on the application of high levels of inorganic and/or organic fertilizer inputs. However, most smallholder farmers can hardly afford to purchase inorganic fertilizers sufficient to produce food enough to feed their families. Nor do they have labour or land to invest in the production of green manures and compost. Therefore, it is imperative that biologically based soil fertility interventions be pursued to improve food security and soil fertility in maize based cropping systems. This led to the establishment of learning centres located in the centre of farming communities as a collaborative effort of scaling out soil enhancement technologies within the innovation platform. Although maize performed well following the best fit legumes in rotation in on-farm learning centres (Table 7) and best fit legumes were highly rated by farmers (Table 8), our results show that farmers grow legumes mainly for food and cash even though many farmers recognize soil fertility enhancement as a major advantage. In 2009/2010 season maize was grown on 1,475 M ha, compared to 0.69 M ha for purses and groundnuts combined (MoAFS, 210). Results from participatory breeding research on cowpea in West Africa also suggested that the prioritization of grain and fodder for sale is of greater importance to resource poor smallholder farmers; soil fertility remains a distinct secondary concern (Kitch et al., 1998).

Using the innovation platform with multiple stake-holders' involvement, farmers previous years' concerns were incorporated in the establishment of learning centres located on farmers' fields. Quality seed of legumes were supplied and planted in the learning centres with involvement of NGOs such as CARE and World Vision. We also note high level of farmer concern about the certified seed. The two key determinants of legume technologies adoption are availability of high quality legume seed (Snapp et al., 2002b; Myaka et al., 2006; Mhango et al., 2011) and the competitiveness of farm gates prices (Snapp et al., 2002b). Grain legume seed is expensive, does not store well and is difficult to multiply. Improved seed delivery strategies may be a prerequisite to any legume intensification strategy. Rubyogo et al. (2010) reported successful use of IP's to disseminate improved bean seeds to 3.8 million households in Southern Africa.

Grain legume yields

Grain legumes are a major source of proteins for most households in Malawi. Groundnut is one of the food legumes grown by a majority of the smallholder farmers in Malawi, primarily for household consumption while improving soil fertility. The mean groundnut yields are low but comparable with values reported for on farm studies (Mhango, 2011). However, the high variability of grain yield between farms within each location can be attributed to differences in soil characteristics, cropping history or field management practices. Further studies are recommended to evaluate adaptation and yield potential of groundnut under different farming environments. It should also be noted that yields above 1 ton ha^{-1} are attainable from on station trials (Kabambe et al., 2008) or on-farm with reasonable soil fertility, good field management practices, and a season with adequate and well distributed rainfall (Kabambe et al., 2008; Mhango, 2011). Groundnut is one of the legumes well fitted as a source of N in maize systems. In a review, Giller et al. (1997) showed that groundnuts stover yields range between 1.4 to 6.7 mgha^{-1} with grain yield range of 1.4 to 2.7 mg ha^{-1} and stover N of 52 to 154 kg ha^{-1}. Groundnut residues are less lignified (approximately 5%, compared to 10 for soybean) and higher in N content as the crop is usually harvested green. However, yields of legumes are generally low on farmers' fields, implying that N return in residues cannot be high.

With harvest index range of 25 to 47%, stover yields from grain yields of 500 kg ha^{-1} as observed in this study can be estimated to 1.06 to 2 and 1.48 to 2.8 mg ha^{-1} for the 0.70 mg grain yield. Up until now, research and extension has not been taken into account, groundnut residues incorporation. There is relatively high degree of labour allocated to incorporating maize residues, while groundnut residues continue to be burnt. This led to experimentation with legume residue incorporation and targeting efficient use of small inorganic fertilizer. Incorporating groundnut and pigeonpea residues led to significantly higher maize yields compared to continuous sole maize. Higher maize yields after groundnuts was consistent across sites, implying that potentially, the groundnut residues mineralized N for subsequent maize, where as maize after maize implies that residues could have immobilized soil N over the short-term. This concurs with Sakala et al. (2000) who observed net N mineralization where senesced pigeonpea leaves were incorporated versus N immobilization where maize residues were incorporated. Planting unfertilized maize implies that less biomass is produced leaving little organic matter to the soil from root decomposition thereby mining the soil further.

For farmers without inorganic fertilizer they are better off planting their fields to grain legumes which can be sold and in the long-term improve the soil fertility status of their fields.

Farmer perceptions of best-fit legume rotations

Adoption of legumes may be hindered by non availability of seed, insects attack, diseases (Snapp and Silim, 1999) and infestations by weeds, among others. The introduction of pigeonpea in most parts of Malawi is threatened by the common practice of open grazing livestock particularly during off season when long duration pigeonpea varieties still remain in the field. Kanyama-Phiri et al. (1998) indicated maize-dominance as the primary reason why farmers in high population density areas show no interest in adopting maize/legume systems despite demonstrated soil fertility enhancement. This is supported by consistent ranking of sole maize by participating farmers across sites especially during this era of government subsidy programme. The data presented here extends these findings and suggests that unless there is a well established innovation platform with multiple stakeholder involvement, sufficient supply of high quality legume seed coupled with legume residue incorporation together with farmer training; adoption of best fit legume technologies is likely to remain low. This report shows cropping systems with multiple benefits that give significant increases in yields with less amount of inorganic fertilizer used. The farm gate price of legumes is about two times higher than the post-harvest price of maize (Phiri, 1999) implying that farmers who can accept best fit legume technologies may realize significant improvement in their livelihood while at the same time improving soil fertility status of their fields.Farmers expressed variations in terms of fertilizer cost, fertilizer access and pigeonpea seed access among sites. Differences in household socio-economic status and site specific characteristics influenced these variations. For example Chioshya is about 30 to 40 km away off tarmac road and market while Mulonyeni and Mpingu have trading centres that sell farm inputs within their boundaries.

Conclusion

From this study it has been observed that farmers will choose to intensfiy best fit legume technologies based primarily on the contribution of the legume to food and cash as well as the availability of legume seed. While soil fertility contributions are recognized, these alone are unlikely to encourage adoption. This two year on-farm experimentation showed that maize grain yields from legume-maize rotaions were significantly higher than ferltilized maize following unfertilized maize. However adoption of the best fit legumes is still a big doubt. Maize following legumes at low N rate (46:21:0 + 4S) gave similar yiekds to sole maize at higher fertilizer rate (69:21:0 + 4S), showing strong benefit of rotations. Overall, results, observations and expeiences from these studies indicate that improvements in soil fertility in developing countries may be pursued if farmers are well trained and if a good legume seed supply stratedy is put in place. We propose that seed regulation should be adjusted to allow for local entreprenuers to package legume seed and sell locally. Currently, registration and inspection costs are high, thus seeds are not certified for local sale.

Community seed production programs for these self pollinated crops could easily manage the isolation and sanitary requirements and raise money for continuity. Small agrodelaers and schools could be some of the beneficiaries if inspections and certification were decentralised to EPAs and for at most district levels.

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