Expl Agric. (2007), volume 43, pp. 437–453 © *2007 Cambridge University Press*
doi:10.1017/S0014479707005339 *Printed in the United Kingdom*

PARTICIPATORY RESEARCH ON LEGUME DIVERSIFICATION WITH MALAWIAN SMALLHOLDER FARMERS FOR IMPROVED HUMAN NUTRITION AND SOIL FERTILITY

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(*Accepted 25 January 2007*)

SUMMARY

Legume species are uniquely suited to enhance soil productivity and provide nutrient-enriched grains and vegetables for limited-resource farmers. Yet substantial barriers to diversification with legumes exist, such as moderate yield potential and establishment costs, indicating the need for long-term engagement and farmer-centered research and extension. This review and in-depth analysis of a Malawian case study illustrates that farmer experimentation and adoption of legumes can be fostered among even the most resource-poor smallholders. Multi-educational activities and participatory research involving farmer research teams was carried out with 80 communities. Over five years more than 3000 farmers tested legumes and gained knowledge of legume contributions to child nutrition and soil productivity. The average area of expansion of legume systems was 862 m^2 in 2005; 772 m^2 for women and 956 m^2 for men indicating a gender dimension to legume adoption. Farmers chose edible legume intercrops such as pigeonpea and groundnut over the mucuna green manure system, particularly women farmers. Interestingly, expansion in area of doubled-up edible legumes (854 m^2 in 2005) was practiced by more farmers, but was a smaller area than that of mucuna green manure system (1429 m^2). An information gap was discovered around the biological consequences of legume residue management. Education on the soil benefits of improved residue management and participatory methods of knowledge sharing were associated with enhanced labour investment; 72 % of farmers reported burying legume residues in 2005 compared to 15 % in 2000. Households reported feeding significantly more edible legumes to their children compared with control households. Participatory research that incorporated nutritional education fostered discussions within households and communities, the foundation for sustained adoption of legume-diversified systems.

INTRODUCTION

Legumes have long been advocated as the missing ingredient for conserving soil resources in low input agriculture, yet farmer production of legumes is minimal across most of sub-Saharan Africa (SSA), and decreasing in many maize-dominated cropping systems of southern Africa (Snapp *et al.*, 2002a). A challenge to the long-term sustainability of cropping systems in developing countries is that food insecure farmers rely on cereal-dominated cropping systems. These offer high calorie production with moderate labour inputs, yet the absence of a significant legume presence reduces nitrogen (N) inputs and recycling of nutrients. Legumes and associated symbiotic

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organisms replenish soil N and recycle nutrients from deep in the subsoil (Phiri *et al.*, 1999). In addition, many legumes have the capacity to excrete root compounds that access phosphorus (P) pools that otherwise remain unavailable (Drinkwater and Snapp, 2007). Legumes not only have the capacity to grow in low fertility environments, they also produce nutrient-enriched foods, e.g. high protein grain and leaves. These are important benefits, but there are many challenges to expanding legume presence in smallholder farming systems.

The objectives of this paper are to elucidate lessons from over a decade of experience with the biological and socio-economic benefits and challenges associated with legume diversification in maize-based systems of southern Africa (Bezner Kerr and Chirwa, 2004; Snapp *et al.*, 1998; 2002b). We use recent findings from a five-year case study of farmer adoption of legumes in northern Malawi, to explore the issues in a specific context.

Legume role in cropping systems

The choice of legume will significantly influence the benefits derived from diversification. Long-season legumes are biologically superior at fixing significant amounts of N, enhancing P availability and yields of subsequent cereal crops, compared to short-duration legumes. The trade-off is that short-duration varieties tend to have the highest yield potential, while contributing fewer nutrients for soil enhancement (Giller and Cadisch, 1995). Farmers may be interested in access to both types of legumes (Kitch *et al.*, 1998). Genotypes that are short-duration and early yielding are often grown to address market niches (e.g. groundnut), whereas long-duration types (e.g. pigeonpea) fit into relay intercrops and subsistence production systems (Rego and Nageswara, 2000; Snapp, unpublished data).

Integration of legumes requires consideration of the competitive effect of relay or intercropping legumes within maize-dominated systems on water and nutrient availability to the main crop. Cultivars of legumes such as cowpea, pigeonpea, mucuna and soybean have minimally competitive growth habit traits, such as late-season branching patterns and deep taproots that minimize intra-row competition (Snapp and Silim, 2002). Relay planting minimizes competition by establishing the secondary crop well after the primary crop is planted. Rotational systems reduce the presence of parasitic weeds and soil-borne pests (Kabambe and Mloza-Banda, 2000).

Soil fertility benefits of legume diversification depend on the legume–cereal ratio, the duration of legume biomass production and residue management. Edible legumes are usually harvested, and their leaves used as a vegetable or for forage thereby reducing nutrient input to the soil. The N benefit of including a grain legume in a rotation has been widely debated; it is estimated as 0–90 kg N ha^{-1} for short or medium-duration soybean and generally higher for a longer-duration legume, such as pigeon pea that grows for about 180 days (Giller and Cadisch, 1995; Hardarson and Atkins, 2003).

Residue management techniques are expected to increase N inputs, but there have been few studies of the effect of burning or residue incorporation on soil N and organic matter over the long-term. A trade-off exists between residue burial and burning.

Labour requirements can be minimized if residues are burned, which reduces the bulk of biomass to be incorporated by hoe, and may also reduce weed pressure by destroying weed seed. Not surprisingly burning of residues in sub-humid to humid smallholder farming systems is a widespread practice (Snapp *et al.*, 2002b). Unfortunately, burning reduces substantially the nutrients present and could jeopardize long-term cropping system sustainability.

Improved understanding of the soil building properties, farmer-acceptability and residue practices is particularly important to minimize requirements for external addition of nutrients. The cost of large doses of soluble nutrient inputs has become prohibitive for most farmers in SSA, as illustrated by a survey of smallholders in Malawi indicating less than one-quarter consistently rely on fertilizer (Snapp *et al.*, 2002b).

Challenges that limit legume adoption

Resource-poor households appear willing to grow legumes in SSA but only at low levels. Surveys indicate that labour requirements, seed access and appropriate genotypes are barriers to legume intensification (Kamanga *et al.*, 2001). Biological properties of legumes pose challenges to farmer adoption of legumes, including: i) the moderate yield of legumes compared to cereals and tubers; ii) the high labour requirement associated with a crop of initially slow growth habit; and iii) relatively few large seeds are produced per plant, necessitating the use of large amounts of seed (on a weight basis) per land area, which substantially increases establishment costs compared to cereals. Socio-economic factors also act as barriers to farmers growing legumes. These include: i) limited and uncertain market access (Zeller *et al.*, 1998); ii) unstable and highly variable prices for legume products across locations and time (Phiri *et al.*, 1999); iii) limited farmer access to seeds of improved legume genotypes (Snapp and Silim, 2002); and iv) insufficient attention by researchers to the multi-functionality of legumes.

Previous on-farm research in Malawi has shown that resource-poor farmers will not adopt legumes based solely on 'ecosystem service' traits such as soil regeneration. Legume varieties must contain recognizable short-term nutritional and market assets to be of interest to smallholder farmers (Snapp *et al.*, 2002b). This has been debated in the literature, where experimentation with on-farm testing and promoting of green manure and improved fallow legume systems is widespread, but adoption elusive (Schulz *et al.*, 2003).

Earlier research found widespread labour constraints to farmer diversification with legumes even in relatively high population density sites of southern Malawi (Snapp *et al.*, 2002a). In this study, carried out at six locations, the farmers at the most northern site – where land was least constrained – were the only ones to express significant interest in a green manure system, *Tephrosia vogelli* relay intercropped with maize. A 'doubled-up' grain legume (DGL) system of groundnut–pigeon pea intercropped with maize had broader appeal. At the central and southern sites most farmers were only interested in the systems which incorporated legume grain production (Snapp *et al.*, 2002a).

Participatory research on legumes

Farmer goals for incorporating legumes in a given cropping system need to be addressed as the starting point. Different markets, household needs and cropping system niches should be identified and options developed for both market-oriented and subsistence production. The impact of a legume on soil fertility, pests, food and nutritional security, and whole system productivity needs to be simultaneously considered. For all of these reasons, participatory research by researchers, farmers and community members that considers the entire farming system is recommended to improve farmer involvement and adoption of varieties (Sperling *et al.*, 2001). A key feature of effective participatory research is an iterative process with assessment and co-learning that involves all partners. Leaf and grain quality and storage traits are critically important to producer and consumer acceptance of legumes (Kitch *et al.*, 1998). There is an array of growth habit traits and branching patterns (above and below ground) that allow a legume to fit into a cropping system as an intercrop or a relay crop (Snapp and Silim, 2002). Minimizing labour requirements must also be considered, taking into account peak labour needs of other crops in the system. This may be achieved by growing competitive legume genotypes that smother weeds, or judicious integration of legumes with cereals or other cash crops. Thus different temporal and spatial niches are addressed through a range of legume growth types and planting arrangements within cereal-based cropping. Innovative approaches are required including nutrition education and outreach to the farmer most involved with legume production, e.g. women in Malawi. An understanding of gender relations, household variation, consumption preferences and household resources can be crucial in determining whether legume introduction leads to positive nutritional outcomes (Berti *et al.* 2004).

Promotion of legumes may require education about the multi-dimensional benefits of crops that enhance soil quality, human nutrition and often have medicinal properties or suppress pests. Trade-offs need to be investigated as legume traits and management systems that optimize food and marketable yield will tend to limit soil benefits.

Case study: legume intensification to improve soil fertility, food security and child nutrition in northern Malawi

Study site description. The research site in northern Malawi is located near the town of Ekwendeni in the mid-altitude region (1200 m) of northern Malawi, on the western side of the Rift Valley. Rainfall is concentrated (~85 %) during the months of November to April, with a long-term average seasonal annual rainfall of 1300 mm. Ekwendeni Hospital staff had noted high levels of child malnutrition and anaemia in their catchment area and attributed these health problems in part to low agricultural productivity. Rising fertilizer costs made them unaffordable for many smallholder farmers. Resource-poor farmers who had malnourished children admitted to the hospital indicated soil fertility was a major source of food insecurity (Bezner Kerr, 2005a).

The cropping system in the area is typical of Malawian smallholders, with the dominant crop being maize (*Zea mays*) and a wide range of other crops grown at low density, including tobacco (*Nicotiana tabacum*), cassava (*Manihot esculenta*), finger millet (*Eleusine coracana)* and sweet potatoes (*Ipomoea batatas)* (Chilima, 2001, unpublished report). Legumes grown prior to the project, in decreasing order of frequency were: groundnut (*Arachis hypogaea)*, bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), soybean (*Glycine max*), Bambara groundnuts (*Vigna subterranean*), and pigeonpea (*Cajanus cajan*).

The hospital initiated the Soils, Food and Healthy Communities (SFHC) project in 2000, as a means to address food insecurity and low soil fertility in the region. The initial hypothesis was that high child malnutrition was linked to low soil fertility and low food security. The pilot research project was implemented to test whether different legume options were viable for resource-poor farmers in the area. Seven villages were selected for the research project, five of which were known to have higher than the regional average levels of child stunting, and two that had a high level of anaemia. The village sampling technique was purposeful sampling (Patton, 1990), as the village areas represented characteristics of particular health problems (malnutrition and anaemia) related to the broader phenomenon of food security. This paper reports on the some of the soil fertility and agricultural results of the project.

Research design

A farmer research team (FRT) was selected by villagers to learn more about different legume varieties and species, test germplasm and management options, and train others in promising technologies. This is based on the participatory model in which small farmer groups carry out research for the broader community (Ashby *et al.*, 1997). Villagers attempted to address the issue of better-off farmers being favoured in farmer participatory research by including farmers from many different groups within the village. The group was composed of a variety of different social groups within the village (e.g. widows, divorced women, highly food insecure, well-off).

Promising legume technologies were chosen based on earlier diversification research carried out in central and southern Malawi (Snapp *et al.*, 2002b). Five legume options were offered to farmers: i) groundnut and pigeonpea intercropped year 1 and rotated with maize year 2; ii) soybean and pigeonpea intercropped year 1 and rotated with maize year 2; iii) maize and pigeon pea intercropped; iv) *Mucuna* spp. rotated with maize; and v) *Tephrosia vogelii* relay intercropped with maize. Maize was planted at three plants per planting station, with planting stations 0.9 m apart, and ridges approximately 0.9 m apart, and hoed by hand following conventional practice. Planting arrangements of the different legume options replicated the densities tested by Snapp *et al.* (2002b). Plant population density was the following: i) groundnut at 74 000 ha^{-1} was intercropped with pigeon pea at 37 000 plants ha^{-1}; ii) soybean at 222 000 ha^{-1} was intercropped with pigeonpea at 37 000 plants ha^{-1}; iii) maize and pigeonpea intercropped at 37 000 plants ha^{-1} each; iv) mucuna density was 74 000 ha^{-1}; and v) tephrosia was established by broadcasting 20 kg of seed ha^{-1} along the maize rows.

Farmer and researcher joint evaluation of the legume technologies was carried out using the 'mother-baby' system pioneered in Malawi (Snapp *et al.*, 2002). Mother trials with all five legume options were located in central village plots, while individual farmers tested 1–2 legume options through on-farm 'baby' trials, which compared farmer current practice to a subset of promising technologies. The FRT maintained the mother trials, with monthly visits from SFHC staff. Plot size for all trials was 10 × 10 m, with no within site replication, and hundreds of across site replications per year (the number varied for each technology as farmers chose which legumes they were interested in testing on baby trials). The number of plots increased every year due to high farmer interest in testing the legumes on-farm (see results section, Figures 1 and 2 below), starting with seven mother trials and 183 baby trials in year 1, which increased to 79 mother trials and 1692 baby trials in year 4.

Survey methods

Multiple quantitative and qualitative methods were used to assess baseline farmer knowledge, agronomic practices and priorities, including semi-structured interviews and focus groups. In addition, each year the FRT monitored farmer participation in trials and preference for legumes. Twenty-one semi-structured interviews were conducted in 2004 to understand agronomic practices, perceptions about legume options and social dynamics with regards to the project.

i) Semi-structured farm interviews (July 2000, n = 30 households). During the first year of the project, the first author and a hospital staff member conducted 30 semi-structured farm interviews to characterize current livelihood strategies and the interactions of food security, soil fertility and health issues (Lightfoot *et al.* 1991). Five interviews were conducted first to pre-test the interview method. Men and women were interviewed separately wherever possible. Prior to the interview, verbal informed consent was obtained. The interview took approximately $1\frac{1}{2}$ hours, and involved a transect, a mapping exercise of their farm and a seasonal calendar of agricultural activities.

ii) Focus groups on soil fertility (August 2000, n = 5 groups, 4–10 people each). Five focus group discussions were carried out to examine villager knowledge of soil fertility, perceptions of legumes, production constraints and household dynamics that may influence adoption. The questions were developed as an iterative process by the entire research team. The selection of the groups was purposive, with groups composed solely of women or men.

iii) Post-harvest agricultural survey (August 2002, n = 350). In August 2002 a survey was carried out which included in-depth agricultural questions. One hundred and seventy-four SFHC households that had children less than five years of age, previously randomly selected for a survey in February 2002, were interviewed on agricultural practices, food security, soil fertility status and perceptions of the different legume options. One hundred and seventy-six 'control' households with children under-five were also interviewed. The control households had been previously selected on the basis of matching food security status and age of children to the intervention household.[1] Informed consent was obtained using a protocol developed by RBK. The survey was designed by RBK, MC and collaborating SFHC staff and was pre-tested in nearby villages by trained enumerators where informed consent was obtained before administering any survey. In married households both husbands and wives were interviewed separately, so the total number of interviews conducted was 650.

iv) Legume choice, farmer participation and crop residue data (2000–2005). Data on legume choice, farmer participation and crop residue burial was collected by the SFHC staff and FRT on an annual basis. FRT members provided a list of new participating farmers and their legume choices for a given village to the FRT chairman (RM). The FRT and SFHC staff developed local indicators for food security, soil fertility and child health in focus group discussions on each subject. The FRT and staff carried out participatory evaluation of all on-farm trials (1000 farmers) using the local indicators. They also visited individual farmers' fields to observe whether crop residues had been buried.

v) Interviews on legume seeds and farmer practice (March 2004, $n = 21$). Twenty-one semi-structured interviews were conducted in 2004 to assess legume seed loss and acquisition, and crop residue burial. Informants were purposively selected by the FRT based on prior knowledge of seed loss and legume expansion. RBK developed the interview guide with input from MC, LS and RM. The research team was made up of RBK, MC, LS and RM in pairs with members of the FRT. RBK conducted training on how to conduct the interview, and the interview was pre-tested and assessed for wording and content prior to conducting the full set of interviews. The researchers visited the fields of the informants to carry out visual observations in addition to asking the questions.

Data analysis

Data entry and analysis of quantitative data were conducted in the statistical software package Statistica (StatSoft, 2006). The legume expansion data were transformed using the square root, as the data were not normally distributed, and the F-test and ANOVA were used to test statistical significance. The residue treatment means were compared using the general association Chi-squared test for equal proportions at $P = 0.01$. Qualitative data were analysed for trends and differences using coding techniques outlined in Miles and Huberman (1994).

[1]Control households were matched to intervention households based on food security status to ensure that differences found were not due to a generally better-off set of households in the participating farmer group.

Table 1. Soil fertility management knowledge was assessed and potential areas for research collaboration identified in 2000, data from semi-structured interviews ($n = 30$) and focus groups ($n = 5$).

Current knowledge and ways farmers improve soil fertility	Knowledge gaps (farmer perspective)	Knowledge gaps (researcher perspective)	Potential collaboration
Fallow land and crop rotations	How to improve soil fertility without the use of fertilizer and with limited land, cash and labour available.	Crop residue incorporation can improve soil fertility, especially if done soon after harvest (a few farmers mentioned this as a practice).	Test residue incorporation of legume options (including tephrosia green manure) under resource-poor, labour short conditions.
Incorporate manure and/or household waste such as ash, maize bran (*gha gha*) into soil.	How to improve food security, especially during the 'hungry season' prior to harvest.	Mucuna can improve soil fertility (this crop grown in the region by only a few farmers).	Test mucuna as an option under resource-poor farmer conditions.
Various soil amendment and conservation measures	How to improve children's nutrition with diverse food sources.	Pigeonpea can improve soil fertility (this crop grown in very small amounts by <20 % of population in region prior to the project).	Test intercropped pigeonpea and groundnut or soybean as an option to improve access to nutritious food and amend soils

RESULTS

Baseline soil fertility management

In 2000, a baseline survey and focus groups documented knowledge gaps and areas for collaboration on soil fertility enhancement, from the perspective of farmers and researchers (Table 1). The project members came in with the assumption that they could both learn from and share knowledge with local farmers.

Farmer legume preference

Most farmers chose edible legumes that could be intercropped together. The most popular choice in the four growing seasons of the project was an intercrop of pigeon pea and groundnut (a DGL system) that was rotated with maize (Figure 1). Over half the farmers selected pigeon pea and groundnut in the first year, and this number increased to 95 % in 2004. A DGL pigeon pea and soybean system was the second most popular choice, with 56 % selecting it in 2004.

According to focus groups and farmer interviews, the high adoption rate of DGL systems appear to be primarily for food use, with soil fertility improvement as a secondary concern. The August 2002 survey findings also indicated that over 70 % of farmers were using these legumes primarily as food, with some using the crops for firewood, seed and sale. Mucuna and tephrosia, on the other hand, were mainly being used for soil fertility improvement.

In the August 2002 survey, farmers in participating and non-participating (control) households were asked if they had fed their children any of the project legumes in the last month, and how often their children had eaten the crops. There was a statistically significant difference between project participants and control households

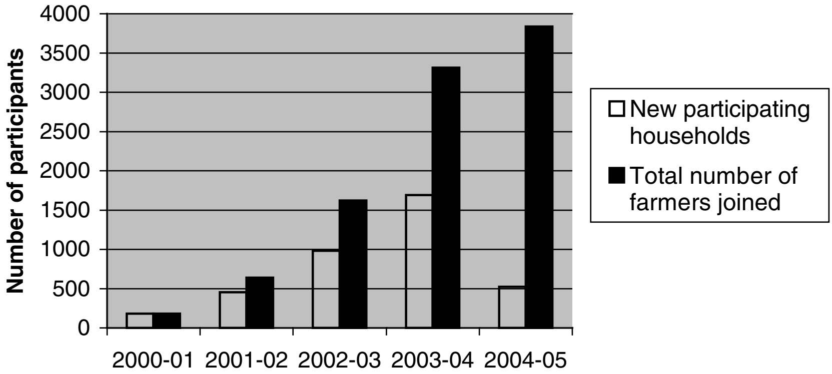

Figure 1. Total number of participants and new participants in SFHC Project 2000–2005.

in frequency of consumption of soybeans and a trend towards enhanced frequency of groundnut consumption among project participants.[2] This difference was tested for other confounding variables, including mother's age, mother's education, mother's main job, child's date of birth, mother's perception of child growth and number of meals a child eats per day. More than half of the project participants who grew pigeonpea and groundnuts reported feeding their children groundnuts either daily or several times a week in the previous month. Slightly fewer than half of farmers who grew pigeonpea and soya reported feeding their children soybean either daily or several times a week. Comments from farmers also suggested that the primary reason they participated in the project was to increase legume production and child nutrition.

Sale of legume harvest was cited by only a few farmers as their primary use for groundnuts, pigeonpea and soybean. Interestingly, a few farmers reported selling mucuna and tephrosia seed, suggesting that local interest in these crops started a new 'market'. A few farmers did sell their edible legumes. In 2002, 18 farmers (16 %) reported a modest contribution of $US 1–5 from the legumes, with groundnuts cited as the highest earner. Since the farmers who were interviewed in 2002 had only grown the legumes for one season on 10 × 10 m plots, these findings are encouraging, in that farmers were gaining modest income from the legumes, as well as a food source. Further evidence of farmers benefiting financially from legume sales was found in 2004. Ten farmers reported selling from $US 4 to 46 worth of groundnuts and soybeans, with an average income of $US 13 reported.[3] Eight of these farmers were older women.

Legume diversification and expansion

Farmer interest in the legume options has increased dramatically in the region (Figure 2). The initial 183 farmer participants has risen to over 3000 farmers in four

[2] $p = 0.0032$ for soybean, $p = 0.08$ for groundnuts, Fisher's exact value test.
[3] The Gross Domestic Product per capita in Malawi was $580 in 2002, and 76 % of the population lives on less than $2 a day, so these very low income reports may be more important than expected in other countries (UNDP 2002).

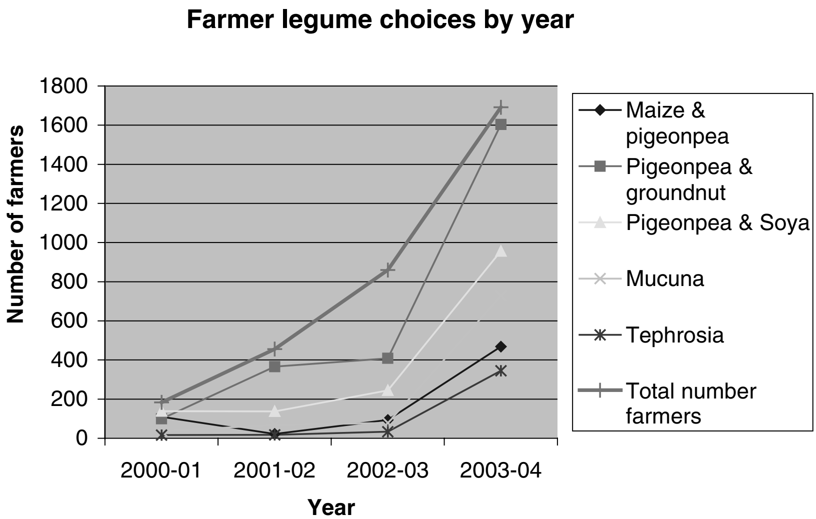

Figure 2. Legume preference of new farmers that participated in baby trials 2000–2004. (Each farmer was allowed to choose 2 out of 5 legume technologies).

years, and the SFHC team have had to limit future numbers due to limited resources. Women's participation increased over time, from 29 % in 2001 to more than 50 % in all subsequent years (50 to 92 %).

Data collected in 2004 and 2005 by the FRT indicated an increase in the size of the fields from the original 10 × 10 m experimental plots, as well as an increase in the number of farmers expanding legume production (Table 2). The average field size in 2004 for groundnut and pigeonpea was 169 m^2; in 2005 it was 862 m^2. A higher proportion of farmers expanded their edible legume fields compared to green manure mucuna, but the degree of expansion was greater for mucuna than for DGL (Table 2). Interestingly, in 2004 male farmers expanded all legume types except pigeonpea and groundnut significantly more than female farmers, and more male farmers expanded legumes (Table 2); however, this difference disappeared in 2005. There was a significant difference in expansion of the different legume types by year. In 2004 farmers expanded more maize and pigeonpea, followed by pigeonpea and groundnut. Only two farmers visited by the FRT in 2004 had reduced their legume plots. In 2005 those farmers that grew mucuna expanded the production area significantly more than other legume systems, and pigeonpea and groundnut/soya more than maize and pigeonpea. There was again a significant difference found by gender: women expanded smaller areas of mucuna and pigeonpea and groundnut than men (Table 2), but the percentage of women expanding all legumes was the same as men.

Soil fertility implications

Many farmers indicated that they were successfully using legumes as an alternative to fertilizer, achieving reasonable maize yields the following year. More than half of farmers reported a dark green leaf colour for a maize crop grown after a legume. All

Table 2. Field observations made by the Farmer Research Team on adoption the legume technology: average (*s.e.*) of area expanded (m^2) differentiated by gender, and number of fields.

Year	Legume option	MU	PPSY	PPGN	PPMZ	All systems
2003/04	Male farmers average expansion (m^2)	113^a (59)	77^a (42)	164^a (49)	322^a (143)	169^a (41)
	Female farmers average expansion (m^2)	15^b (5)	30^a (20)	164^a (107)	10^b (0.9)	92^b (34)
	All farmers average expansion (m^2)	89 (26)	63 (30)	164 (47)	250 (115)	148 (33)
	Total number of fields	8	17	29	13	67
2004/05	Male farmers average expansion (m^2)	1538^a (176)	859^a (61)	924^a (116)	275^a (124)	956^a (104)
	Female farmers average expansion (m^2)	1237^b (124)	935^a (90)	786^b (76)	270^a (167)	772^b (73)
	All farmers average expansion (m^2)	1429 (114)	891 (56)	854 (81)	271 (103)	862 (61)
	Total number of fields	11	33	55	11	110

Means followed by different letters within a column are statistically different at $p < 0.05$.
MZ: Maize; PP: Pigeonpea; GN: Groundnut; SY: Soybean.

farmers growing tephrosia reported dark green maize leaves in the following crop, while among those growing mucuna 79 % reported dark green leaves. Farmers that grew pigeonpea and soybean or pigeonpea and groundnut intercrops reported 70 % and 60 %, respectively, for subsequent dark green maize, whereas only 40 % of farmers growing maize–pigeonpea intercrop reported dark green maize. A similar approach to this indicator to assess legume contributions to N fertility involves calibrated leaf colour charts (Shukla *et al.*, 2004), which has been used very successfully by researchers working on N management in wheat and rice systems.

Residue management

The project has influenced farmers to alter crop residue management, including the timing of incorporation. Interviews in 2000 indicated that 15 % of farmers buried legume residues. In 2002, 33 % of participating households reported burying some crop residue, and 39 % of participating households reported burning crop residue, compared to 55 % of control households burning some crop residue. This distribution was not significantly different from equal proportions (0.33 each). From 2003 to 2006 an educational priority of the FRT was to promote the benefits of early crop residue burial, through demonstrations, field visits and 'residue burial promotion days'. In 2005, observational data collected by the FRT on residue management practices showed a significant difference from equal proportions as only 12 % of farmers did not bury residues (Table 3). There was also a significant difference by treatment, with a greater number of farmers burying mucuna than soya or groundnut (Table 3). Fifty-five percent of households were burying groundnut residues soon after harvest, 77 % of those growing mucuna buried them early, while only 34 % of soybean residues were buried early. Farmers reported that the need to thresh soybean at the homestead made it a more difficult legume crop to bury.

Interviews in 2004 indicated that loss of one legume seed type was common, but only one farmer of 21 interviewed had lost *all* the legume seed types initially provided by the project. Out of the 21 farmers interviewed, fewer than half (10 farmers) had lost at least one legume seed.

Table 3. Residue management practice in 2004 and 2005 among participating farmers, evaluated for preferential early incorporation of legume residues using the general association Chi-square test for equal proportions.

		Farmers reporting residue management practice (% of total)‡			
Legume	No. of fields	Incorporate early	Incorporate late	Burn/leave in field	$p >$ Chi^2
Groundnut 2002	323	86 (26)	99 (31)	138 (43)	NS†
Groundnut 2005	192	105 (55)	52 (27)	35 (18)	<0.01
Soybean 2005	177*	61 (34)	24 (14)	15 (8)	<0.01
Mucuna 2005	106	82 (77)	18 (17)	6 (6)	<0.01

‡The % numbers do not add up to 100 as there were data missing from this set ($n = 77$).
†NS: not significantly different from equal proportions.

There were numerous problems that prevented some farmers from expanding legumes. Livestock was one problem, particularly for pigeon pea expansion, because pigeonpea is harvested late in the season, after the maize harvest, at a time when cattle are usually allowed to graze freely. The small amount of seed given by the project was the second most common reason cited. Pest problems associated with pigeon pea (i.e. beetles and weevils) and low soybeans yields were also mentioned. At times community and household dynamics affected a farmer's ability to expand the fields. One farmer had his fields seized by the village headman once the soil had been improved, and thus lost his seed source and years of labour spent improving the soil. Another farmer's husband died, and she lost the land that she had been working on with the legumes to her husband's family. It took several years before this widow could obtain enough seeds to try these legume options again, but she was successful three years later in growing maize after maize and pigeonpea.

DISCUSSION

The findings on farmer knowledge of soil fertility support earlier participatory research in Malawi, as farmers placed a high priority on identifying technologies that were less cost-prohibitive than fertilizer but addressed soil nutrient problems and improved the productivity of maize-based cropping systems (Kanyama-Phiri *et al.*, 1998). Among researchers, legume-based options were seen as high priority technologies. Based on earlier research with smallholders in central and southern Malawi, researchers were interested in testing the potential of legume integration and residue burial to improve fertility. The absence of sufficient livestock manure in Malawi and risks associated with high cost fertilizers contributing factors to the interest in legumes (Bezner-Kerr 2005a).

The project combined two different paradigms of knowledge: participatory research vs education or knowledge sharing (e.g. benefits of legume residue burial, increased legume consumption). At times this combination of approaches (participatory research and education) clashed with each other; e.g. project staff took a 'teaching' rather than 'research' approach to planning research activities. Nonetheless, this approach has led to a useful combination of learning from farmers, while also contributing useful

https://doi.org/10.1017/S0014479707005339 Published online by Cambridge University Press

knowledge based on critical gaps identified from research and dialogue. The mother-baby farmer participatory research approach combined with a FRT has proved very successful in spreading information about legume options to other farmers. The FRT attributed the marked increase of women participating in 2002 to the severe famine that year, suggesting that women placed high priority on food security and nutrition. The role of the FRT has been a key component in the success of the project so far, and their increased capacity to carry out research, participatory education and community improvement activities has been a major benefit of the project. They hope to expand their research activities beyond the initial legume options in the future, and have begun exploring cowpea, sorghum and climbing beans as other crops to test.

Farmer preferences for grain legumes over a four-year period highlight the critical importance of providing a food source for food insecure farmers with legume options and support the findings of other studies, that an emphasis on edible grain legumes may be a sustainable long-term objective for researchers (Schulz *et al.*, 2003). In all years, more farmers preferentially chose pigeonpea and groundnut to expand over other legume options, followed by pigeonpea and soya. Female farmers also had, on average, smaller legume areas, while more male farmers expanded mucuna. Differences between men and women farmers in the area expanded and the *type* of legume expanded indicate the importance of understanding how gender dynamics influence access to land, labour and preferences for household use.

The project is building on local knowledge and previous legume promotion efforts. Groundnut was already grown in the area and was a popular choice in part due to the improved variety (CG7) distributed by the project, a variety which has been shown to require less labour to harvest than traditional groundnut varieties (Edriss and Mangisoni, 2004). Farmers who chose soybean were largely interested in improving child nutrition. The hospital has promoted soybean as a complementary food in porridge for young children since the 1980s and this appears to have been a successful educational exercise (Bezner Kerr, 2006). Thirty percent of expanders in 2005 chose pigeonpea and soybean (Table 2).

Pigeon pea was typically grown in very small amounts prior to the project; 20 % of households grew pigeon pea in the 2000 season. This legume was popular because it is harvested late in the dry season, and thus provides a food source when most other legume options are exhausted. Farmers typically coppiced pigeonpea (cut the plant back to the main stem after harvest which encourages regrowth and a higher yield in the second year) intercropping the two-year-old plants with maize the following year, thereby growing grain legumes two years in a row, or 'doubled-up grain legumes' (DGL) (Snapp *et al.* 2002a; 2002b). This farmer innovation meant that farmers had DGL followed by grain legumes intercropped with maize rather than followed by sole-maize, which was the original recommended system. This farmer-designed technology provided large amounts of legume residue for soil fertility improvement, while at the same time ensured production of three nutrient-enriched legume crops in conjunction with a maize crop, an improvement over the researcher-designed system of two legume crops for every maize crop. Field observations by the FRT in 2003–05 suggest that the doubled-up pigeonpea options were being expanded and were the option of choice for female farmers. Fifty percent of expanding farmers chose this option in 2005 (Table 2).

Maize and pigeon pea were initially selected by 60 % of farmers. The familiarity of farmers with intercropping maize with a legume, and the opportunity to grow maize may have been the reason for high uptake in the first year. Many farmers observed, however, that maize and pigeon pea did not help maize growth much the following year. This information may have reduced interest in maize and pigeonpea in the following years, as farmers shared their experiences with others. Farmers chose instead to grow maize with pigeonpea after growing DGL. FRT data indicate that some farmers (10 % in 2005) are expanding this option (Table 2).

Mucuna was chosen by few farmers in the first three years of the study (10–20 %) (Figure 1). Mucuna seed contains L-dopa, a phytochemical that can lead to gastrointestinal problems and even death. The seed must be cooked for at least 6 hours to reduce L-dopa content to safe consumption levels (Versteeg *et al.*, 1998). The FRT and SFHC staff decided that the crop would not be actively promoted as a food source because of concerns about labour and fuelwood requirements. Initially there was high uptake of mucuna due to both its potential as a market crop and for soil fertility improvement. However, the poisonous attributes of mucuna in the communities reduced interest; in some cases grandmothers threw out the mucuna seed, due to fears of poisoning young children (Bezner Kerr and Chirwa, 2004). Although farmers rated mucuna the highest for improving soil fertility, this reason was insufficient for adoption. Farmers were generally unwilling or unable to set aside land solely for soil fertility improvement. As one agricultural extension worker put it, 'They [local farmers] do not get that [using legumes to improve soil fertility]. They say that is a long-lasting idea. Most farmers need immediate impact.' The FRT decided to promote mucuna as a green manure actively, based on farmer assessment and research indicating it was highly effective for improving soil fertility and maize yields (Snapp *et al.*, 2002b). Education was conducted on mucuna and utilization to ensure that farmers were fully informed about the crop. Adoption of mucuna increased after education and training was conducted, and some farmers (10 % in 2005) have expanded their mucuna area considerably (Table 2).

Interest in testing tephrosia remained under 20 % for all four years of the project. Focus group discussions indicated that since tephrosia was considered more of a tree, and women were less interested in it as an option, because trees are usually considered 'male' property in this part of Malawi. This finding is in keeping with other studies on trees and gender roles, highlighting how awareness of social norms for tenure and gendered responsibility needs to be considered in farming system diversification projects (Place and Otsuka, 2002).

Farmers involved in the project observed that the edible legumes, when residues were buried, provided adequate fertilizer to replace the first fertilizer application. These findings are supported by on-farm research in central and southern Malawi, where legumes have been shown to provide about 50 kg N ha^{-1} equivalent of nutrients to subsequent maize crops (Phiri *et al.*, 1999). The combination of legume rotations and modest inorganic fertilizer application is consistently associated with maize yields that are 60–110 % higher than a control maize crop (Kamanga *et al.*, 2001; Snapp *et al.*, 2002b).

The increase in early crop residue burial is a dramatic change from conventional management practices, as surveys in central Malawi have shown that approximately half of the fields are burned over and the remainder managed through late burial of residues at land preparation, approximately four months later than early incorporation of residues (Snapp *et al.*, 2002a).

Reasons for legume seed loss included eating the seed, livestock or birds eating the crop, beetles, weevils or other pests destroying the seeds. Some people reported low crop yields because they had had a death or illness in the family that had reduced their ability to work on the fields. Other people reported late planting because of a need to do on-farm casual labour to obtain food and seeds, and the late planting had resulted in poor yields. In addition, some people had eaten their seeds because of a lack of food. In other cases, there was a lack of interest in maintaining a specific legume. Findings on land seizure improved by legume production (e.g. from widows and tenants) suggest that the project needs to be sensitive to gender and community dynamics that prevent farmers from using the legume options.

Institutional challenges also remain, including maintaining FRT enthusiasm and managing the success of the project without overstretching staff and resource limits (Bezner Kerr and Chirwa, 2004). The mother-baby trial approach has had mixed results. Despite initial project negotiation and agreements with communities about village plots and seed distribution, in some villages there have been conflicts over who is responsible for maintenance of the village plots (i.e. the 'mother' trials). The FRT has suggested that all participating project farmers should contribute labour, while participating farmers have argued that the FRT is primarily responsible for village plots. Village disputes over seed distribution from the mother plots have been common, including some village headmen seizing all the seed after harvest. The FRT has also reported that the experimental size of the plots (10 × 10 m for each option) leaves very little seed for use within the community. Nonetheless, some villages have effectively used the village plot seed for distribution to food-insecure households.

Interestingly, the FRT has insisted on retaining the village mother plots as 'blackboards' for learning, and suggest that they provide an informal source of information and teaching to others. This supports an assessment of participatory research methods that found mother trials were seen as everyone's research site, supporting community discussions and learning, while baby trials in this cultural context were perceived as belonging to a farmer and access was related to kinship lines (Johnson *et al.*, 2003). As one FRT member said, 'People will not go to other people's farms to learn about the legumes, but they will go to the village plots.'

CONCLUSIONS

This review and case study highlights the importance of considering farmer preferences for edible legumes. We suggest the importance of building on this interest through education about legume nutritional benefits for family members and soil building

https://doi.org/10.1017/S0014479707005339 Published online by Cambridge University Press

properties. A gender difference in legume preferences was observed, in agreement with earlier indications that women smallholders in SSA tend to favour legume options that improve food security and do not choose green manures or tree legumes that are associated with male responsibilities and tenure. Women are also expanding smaller areas of production.

In this case study and earlier research in Malawi, farmers expressed a clear preference for experimenting with DGL, although there has been ongoing interest in green manure legume systems. This preferred legume-diversified system was most commonly a groundnut–pigeonpea intercrop, followed by a soybean–pigeonpea intercrop. Farmers often planted a maize–pigeonpea intercrop after a DGL crop to enhance soil fertility effects. The long-term impact of legumes will be determined largely by the extent and intensity of legume integration into cropping systems, and agronomic practices such as how residues are managed. An exciting result from this case study was the observation that an integrated education and participatory research approach was associated with significant adoption of residue incorporation, replacing the common practice of residue burial. Legume residues were preferentially incorporated and planted to maize, with subsequent improvement in maize leaf colour and yields, as reported by farmers.

This successful case study shows that after four years, over 3000 farmers had tested legume technologies, with evidence for considerable legume expansion and diffusion. The slow seed multiplication ratio of legumes limited market options and reinforced the need for long-term investment in seed multiplication. Continuing support for farmer participatory experimentation is required to enhance local capacity to solve the considerable challenges and document benefits associated with legume diversification in maize-based systems.

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