MAIZE-LEGUME ROTATIONS IMPROVE SOIL HEALTH AND CROP PRODUCTIVITY

Background

Maize is the most widely grown food crop in Malawi and is crucial for food security in a country whose economy is mainly based on agriculture. However, average maize yields are low and are declining in some areas. This is partly due to limited adoption by smallholder farmers of improved varieties but also because the fertility of the soil is declining. Inorganic fertilisers can increase maize yields in the short run, but are expensive to buy and are not always available to smallholder farmers. To maintain longer-term soil health, it is important to build organic matter to ensure efficient nutrient cycling and to enhance water-holding capacity. The Malawian government has sought to support farmers and boost the economy by subsidising seeds and fertilizers through the Farm Input Subsidy Programme (FISP). The programme has delivered positive outcomes but resource constraints mean that not all farmers can be reached. Also, it is evident that subsidies are not sustainable in the longer term.

The average farm size of farmers in Malawi is around 0.8 hectares. There is little new land available to bring under cultivation and so the only opportunity to increase the output of maize and other food crops is by intensifying production on the existing land area. One way to increase productivity on small land holdings, while diversifying diets, is to intercrop or rotate different crops. Grain legumes intercropped with maize provide multiple benefits. Legumes fix atmospheric nitrogen and their residues provide soil carbon, so they help to maintain or restore soil health and fertility. The grains are a rich source of proteins and oils, and the inclusion of legumes in the cropping system helps to diversify the diet and contribute to improved nutrition of farm families. The heavy dependency on maize in Malawi restricts the choice of food in the diet and this is a particular problem for women and young children.

CCRP response

The Collaborative Crop Research Program (CCRP) of The McKnight Foundation promotes the principles and practices of agro-ecological environments, which aims to improve the performance of agriculture systems by integrating ecological principles into farm management. Improved performance can be associated with various factors including increased productivity, enhanced use of local resources, improve livelihoods and more diverse diets. To investigate how maize-based cropping systems in Malawi could function more sustainably, the CRRP commissioned a research project led by Bunda College of Agriculture. The 'Best Bets' project began in 2006 and is led by Professor George Kanyama-Phiri, who has been conducting research on agroecological issues for smallholder farmers in Malawi for over two decades.

Research aims and approach

The Best Bets project is now in a third phase and aims at sustainably enhancing the productivity of smallholder farming systems in different agroecological environments in Malawi. It also aims to improve nutritional diversity of farm families, particularly for children under five years of age and for pregnant women. The project seeks to achieve these aims through strengthening innovation based on farmer-led priorities and farmer evaluated technologies. "It aims at improving crop productivity and soil health through integration of grain legumes in maize based systems. The project is promoting sole and doubled-up legumes involving pigeonpea, groundnut, soybean and cowpea. Doubled-up legumes involves intercropping two legumes with complementary growth habits. These legumes are

rotated with crops such as maize to take advantage of the fertility left behind by the legumes," says Professor Kanyama- Phiri. "Since a lot of smallholder farmers are poor and unable to afford the high price of inorganic fertilizer, the project will help farmers to achieve multiple benefits of improved soil fertility, enhanced crop productivity, and better family nutrition," he adds.

The project is working in Kasungu and Ntcheu districts in the central region of Malawi and Mzimba district in the northern region. The sites have differing rainfall patterns and soil types. "The idea is to identify the technology options that will be most suited to that particular niche or environment in order to improve the agricultural production and livelihood in a sustainable manner" Professor Kanyama-Phiri says. At the start of the project, which initially focused on Kasungu district and the Ekwendeni area of Mzimba district, the project team engaged with lead farmers and government extension officers to jointly identify key research issues. Participatory research was then conducted with farmers in which 'mother' trials were used to demonstrate technologies and 'baby' trials enabled farmers to try out selected practices in their own fields. Field days and farmer feedback workshops were conducted to discuss experiences and share results.

A 'doubled-up' legume system: a groundnut-pigeonpea intercrop

Legumes bring benefits

Results from the first four-year phase of research confirmed that continuous sole cropped unfertilised maize produced low yields of less than one tonne per hectare on average. Integrated soil fertility management involving a legume in a rotation and adding a low dose of inorganic nitrogen fertiliser (24 kg N/ha) gave higher maize yields than a continuous sole cropped maize with a similar amount of fertiliser (see Figure 1). The doubled up legume technology, pigeonpea intercropped with soybean or groundnut and then rotated with maize, produced the best returns to land and labour invested. It also led to very high fertilizer use efficiency. On sandy soils in Kasungu, the pigeonpea-groundnut intercrop fixed 83 kg N/ha compared to 56 kg N/ha and 54 kg N/ha for a sole crop of groundnut and pigeonpea, respectively.

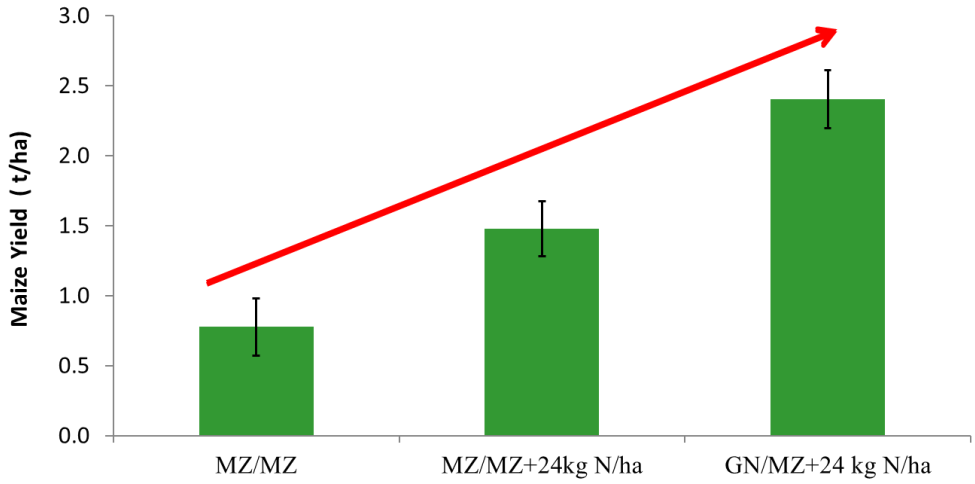

Figure 1: Maize yield under continuous maize (MZ/MZ) with and without inorganic nitrogen fertiliser and a groundnut/maize (GN/MZ) rotation with inorganic nitrogen fertiliser in northern Malawi. Bars indicate standard errors (Mhango *et al*., 2011).

Over two seasons of evaluation, over 80% of the farmers involved in farmer research groups at the Ekwendeni research site indicated that they would like to grow more of the doubled-up legume technology. Twenty percent of farmers expressed interest in growing a maize-pigeonpea intercrop. Similar responses were provided by farmers in Kasungu. Consequently, during a second phase of the research, the project sought to extend the benefits of legume diversification through expanded legume knowledge and use. There was a special focus on households affected by HIV-AIDS and the project worked in collaboration with Ekwendeni hospital's Soils, Food and Healthy Communities initiative (SFHC) to conduct participatory trials, hold field days and provide nutrition education. Legume recipes were included in the nutrition education and both men and women took part in the training.

Sisiwe Luhana with her maize crop grown after groundnut and applying 24 kg N/ha of inorganic nitrogen fertilizer

Malibase Botha from Bwengu Extension Planning Area (EPA) in Mzimba has noticed that her legume crops have boosted the fertility of the soils on her farm. "The good thing about planting legumes is that you don't apply fertiliser when you rotate with maize. This is helping us save on inputs", she says. Sisiwe Luhana is also happy that she now has to buy less fertilizer as the legume residues in her crop rotation adds nitrogen and organic matter to the soil. She observes that the residues help to retain moisture during dry spells. This is something the project team has investigated through a modelling approach. Their findings suggested that both intercrops and rotations are likely to perform better than monoculture maize under conditions of increasing temperature and more varied rainfall. This was true for the majority of locations and soil types in the simulated conditions.

Differences in response to legumes

One of the challenges identified during the research is that the performance of legume systems varies between and within locations. This is thought to be due to a combination of biophysical and socioeconomic factors, but the way that these factors influence system performance is not well understood. On-farm trials were carried out in Kandeu and Manjawira EPA in Ntcheu district in which maize response to different interventions was investigated. The interventions included different legume crops, inorganic nitrogen and compost. Some fields seemed to respond to each intervention, whereas other fields seemed not to respond much to any intervention. Similarly, considerable variation between farms in maize yield following doubled-up legumes was observed in Kasungu. Figure 2 shows that on some farms there was a large increment in maize yield following legumes whereas there was little difference in yield on others. The project team is currently conducting research to investigate the factors that cause the wide variation in benefits that farmers obtain from the technology. It is known that soils with critically low levels of organic matter are non-responsive, and there may be other factors that also contribute to poor intervention responses.

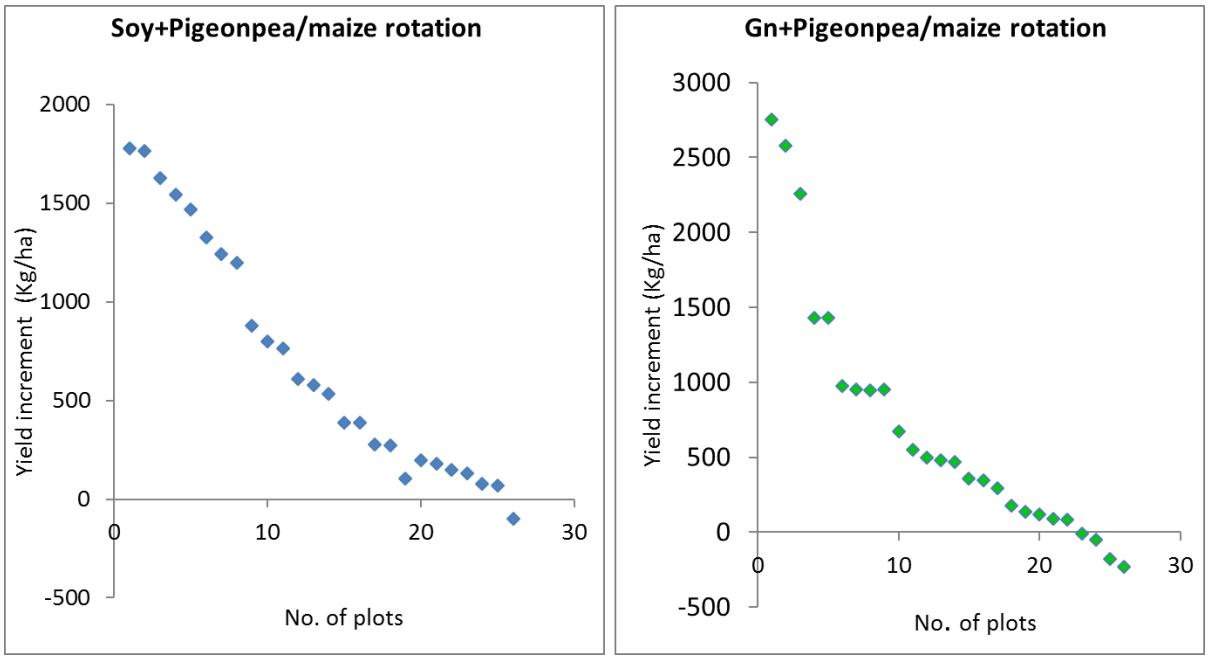

Figure 2: Maize yield increment following legumes versus continuous maize in Kasungu district

Dr Wezi Mhango, soil scientist at LUANAR and co-Principal Investigator of the project, explains the approach being used. "We are using multi-environment trials (MET) to develop a better understanding of the factors influencing variability in the performance of maize-legume cropping systems in Malawi", she says. One of the factors under consideration is the effect of variation in farm management on crop performance. Dr Mhango has developed a MET protocol to assess the impact of factors such as

Project team members Kate Wellard, Wezi Mhango and Prof. Kanyama-Phiri meet with farmer collaborators in Ntcheu District

planting date, time and frequency of weeding, control measures for pests and diseases. The findings should help to explain why farmers like Linely Chavula, a lead farmer from Zombwe EPA in Mzimba district, did not obtain yield benefit from pigeonpea and soya in her system.

As with previous on-farm trials in the project, the MET are being conducted with lead farmers. Each lead farmer has about 20 follower farmers who take part in the trials and try out the technologies on their own farms. A new development in some locations in the project is the linking of farmers, researchers, extension officers and other stakeholders in farmer research networks (FRN). FRN is a new approach through which farmers are engaged as equal partners of scientists, development agents and other relevant stakeholders in generating, adapting and scaling out innovations. The project is investigating the potential of the FRN model to facilitate building the capacity of smallholder farmers to engage in the innovation process within the maize legume farming system. The research is being conducted by a PhD student from LUANAR, Frank Tchuwa, under the direction of Dr Daimon Kambewa (Extension Department, LUANAR) and Dr Kate Wellard (Social scientist at the University of Greenwich in the UK).

Lead farmers involved in on-farm trials in Ntcheu district

So far there has been a positive response from farmers to the participatory research being conducted in the MET. In Ntcheu district, the Lipangwe Organic Manure Demonstration Farm (LOMADEF), a partner organization in the project since 2010, has seen improvements in yield resulting from project activities. Thomics Lupenga, LOMADEF Executive Director, says that the project has helped farmers in the area to improve their soils and they like the technologies the project is promoting. “Instead of making manure, which is laborious work, LOMADEF farmers have embraced the technologies of crop diversification of legumes and cereals that the project is promoting,” he says. Similar reactions from farmers have been observed in other project locations. However, some challenges remain. Patrick Kanyika, Agriculture Extension Development Coordinator in Bwengu, says soil fertility in his area has been a concern for years and crop yields have dropped sharply. Consequently, farmers are receptive to new ideas but still need to be convinced. “Most farmers are interested and what is needed is to increase size for plots where trials are being conducted. When we use small plots some farmers fail to appreciate the impact,” says Kanyika.

Influencing policy processes

The project has generated a considerable amount of evidence on the advantage of including legume crops in maize-based systems (see Box 1). However, the full benefits of the research will not be felt unless there is support among decision-makers and practitioners for the promotion of the improved practices. Accordingly, the project team has prepared policy briefs and held workshops to which government officials are invited and briefed on the new technologies. Parliamentarians have also been engaged through a link with the Parliamentary Committee on Agriculture. These efforts have borne fruit with the adoption by the Ministry of Agriculture, Irrigation and Water Development of doubled-up legumes as one of the technologies it is promoting.

Box 1

Achievements of the project

- Farmers at the project sites are now obtaining **maize yields of up to 1.5 t/ha** compared to 0.5 t/ha before.
- The significant contribution of legumes to **soil nitrogen reserves** has been documented.
- Results have shown an **increase in soil organic matter** when legumes are included in the cropping system.
- Crop modelling studies have shown that with climate change, integration of legumes in maize based systems **can reduce the risk of failure** compared to continuous maize with or without fertiliser
- The **doubled-up legume** technology involving groundnut and pigeonpea is being promoted by the Ministry of Agriculture Irrigation and Water Development.
- A **PhD student and several Masters students** have graduated successfully and made important contributions to the research.

Next steps

The project will continue to explore factors affecting the heterogeneity of response in individual farms from integrating legumes into maize-based cropping systems in Malawi. Further multi-environment trial activities will be conducted at the three project sites in Mzimba, Kasungu and Ntcheu districts and these will make use of the innovative work with low-cost sensors to measure soil and plant characteristics. The research is expected to help farmers to understand what practices work best for them in their own situation and the MET approach will be evaluated to see how it can contribute to scaling out the adoption of legume technologies.

Joint farmer-researcher experimentation is at the heart of the MET approach. The project will assess the potential for farmer research networks to build farmers' capacities to engage in agricultural innovation and generate maize-legume practices that enhance the productivity of their farms in a sustainable way whilst improving their livelihoods.

Lessons learnt

The project has shown that it is possible to enhance the productivity of maize-based systems without relying heavily on inorganic fertilisers which are expensive, not universally available and do not contribute to the maintenance of soil fertility. Through incorporating legumes into a rotation, system productivity may be increased and soil health and fertility can be maintained or enhanced.

Integrating legumes into maize-based cropping systems is a sustainable solution but how this is done depends on local contexts. Locations vary in biophysical characteristics such as soil type and climate. They also differ in social and economic factors such as attitudes and perceptions of farmers and their access to input and output markets. Consequently, recommendations on the choice of crops and how to manage them need to be tailored to the local context.

Multi-environment trials (MET) enable researchers, farmers and agricultural extension staff to jointly identify and test locally adapted solutions across a range of socio-ecological environments. MET need careful planning to ensure that all parties endorse the purpose and approach and understand their roles in data collection and analysis. Communication and data gathering in MET can be facilitated by the use of information and communication technologies and the project team is gaining useful experience in experimenting with low cost sensors and open source software.

The project has made an important contribution to policy change in Malawi. This has been achieved by generating evidence from a series of well-planned trials and engaging effectively with policy makers.

Project team members

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