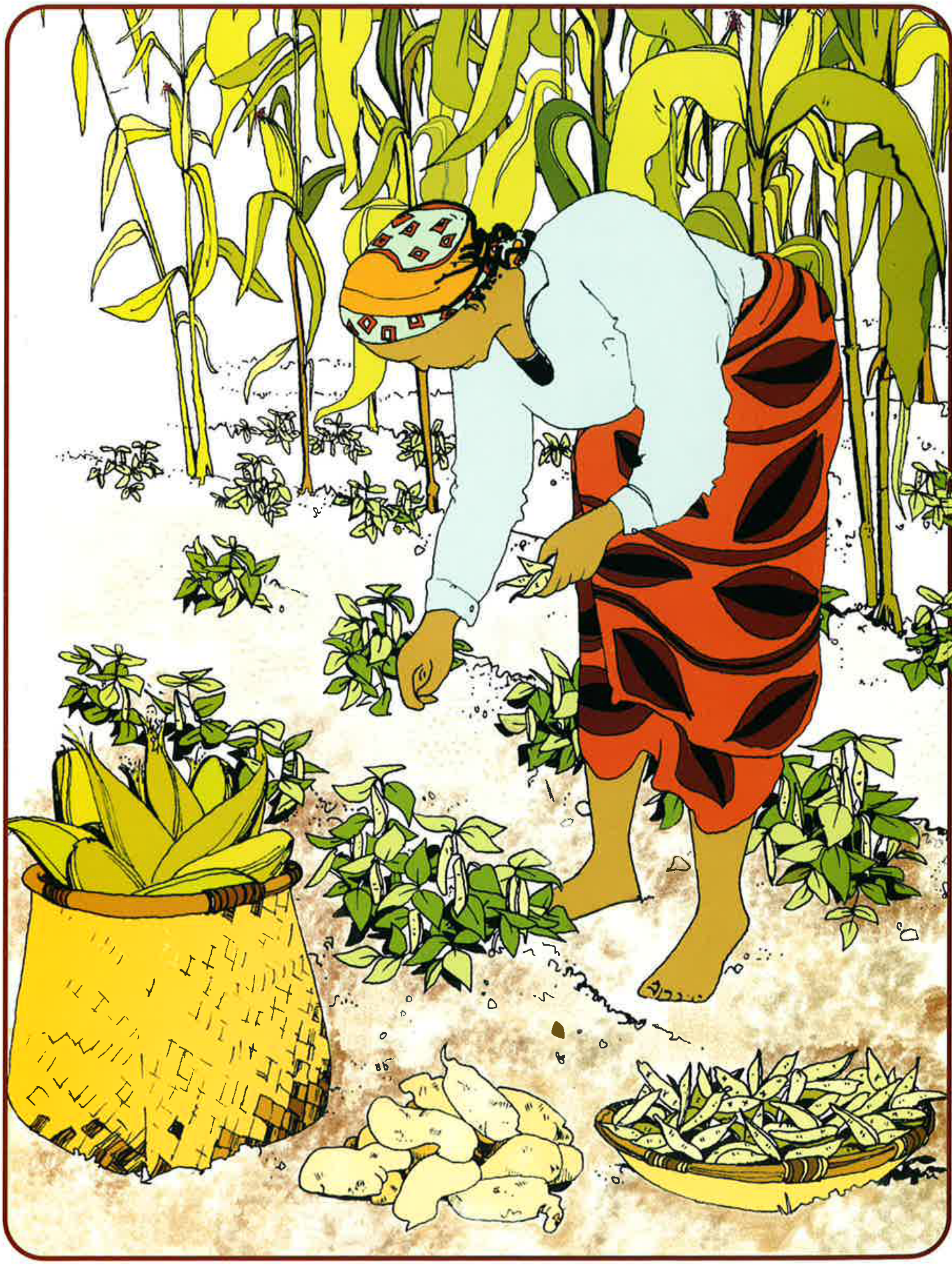
INTEGRATED CROP MANAGEMENT RESEARCH IN MALAWI: DEVELOPING TECHNOLOGIES WITH FARMERS



REPUBLIC OF MALAWI

MINISTRY OF AGRICULTURE AND IRRIGATION

DFID Department for International Development

Natural Resources Institute

FARMING SYSTEMS INTEGRATED PEST MANAGEMENT PROJECT

INTEGRATED CROP MANAGEMENT RESEARCH IN MALAWI: DEVELOPING TECHNOLOGIES WITH FARMERS

PROCEEDINGS OF THE FINAL PROJECT WORKSHOP,

CLUB MAKOKOLA, MANGOCHI, MALAWI,

29 NOVEMBER–3 DECEMBER 1999

EDITED BY

J. M. RITCHIE

REPUBLIC OF MALAWI

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DFID Department for International Development

Natural Resources Institute

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Natural Resources Institute

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"...whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country than the whole race of politicians put together"

Jonathan Swift

Contents

Welcome to participants

A. T. Daudi

Manager, Farming Systems Integrated Pest Management Project, PO Box 5748, Limbe, Malawi

I welcome you all to the final workshop of the Farming Systems Integrated Pest Management (FSIPM) Project.

The FSIPM Project started in 1996 with a Stakeholder Workshop at the Shire Highlands Hotel in Blantyre to which some of you were invited. The project worked in the two Extension Planning Areas (EPAs) of Mombezi and Matapwata in the four villages of Magomero and Kambuwa (Matapwata EPA) and Lidala and Chiwinja (Mombezi EPA). Both EPAs are in Blantyre Agricultural Development Division (ADD).

Management of the project has involved fortnightly management meetings and half-yearly steering committee meetings. The members of the Steering Committee include staff from the Departments of Agricultural Research, Extension, and Crop Production, Bunda College of Agriculture, the UK Department for International Development (DFID) and NGOs. The findings of the project have been disseminated through internal reports and presentations during project meetings.

Much progress has been made in the area of human resource development. Six Malawians have been trained in the UK at M.Sc. and diploma levels in crop protection, agricultural economics and social anthropology. Five students have been trained at Bunda College at M.Sc. level and some officers have been trained through workshops, seminars and short courses abroad.

The project is building a new hostel (25/26 rooms) at Bunda College. The old plant protection building at Bvumbwe Research Station is being rehabilitated and the renovation will be extended to the plant quarantine building.

Officially the project ended on 30 September 1999, however, it was extended for six months to 31 March 2000 to allow this final workshop to take place and for all the project results to be documented.

I now invite the Director of the Department of Agricultural Research and Technical Services (DARTS) to officially open this workshop.

Opening address

A. P. Mtukuso

Director for Agricultural Research and Technical Services, Ministry of Agriculture and Irrigation, Malawi

Dr Potter, DFID Field Manager, Representatives of the academic and NGO communities, Distinguished visitors from overseas, Ministry and FSIPM Project staff, Ladies and Gentlemen.

It is a pleasure to be with you today at the start of this final workshop of the Farming Systems Integrated Pest Management (FSIPM) Project, entitled *Integrated Crop Management Research in Malawi: Developing Technologies with Farmers*.

We are meeting at that time of the year when farmers once again are staking their skills and experience against the forces of nature in their struggle to feed their families and achieve a sustainable livelihood. Against that background it is appropriate that we are gathered together to review what has been learned about improving yields of food crops grown by resource-poor smallholder farmers, not only by the FSIPM Project but by other research groups who have also been working with farmers in the same endeavour.

The Ministry of Agriculture's Strategy and Action Plan published in 1995, drew attention to the fact that per capita food production in Malawi has been falling in recent years while average calorie consumption is still below the recommended daily requirement. Several initiatives were proposed to address these problems, with the aim of improving household food security and raising farm household incomes while conserving natural resources, against a background of rising population, increasing land shortage and declining soil fertility. In particular, it was recognized that resource-poor households, especially female-headed households, needed to be targeted in the development of appropriate technologies and approaches to increase productivity.

The Strategy and Action Plan advocated a participatory approach in which research scientists and extensionists would work closely with farmers to identify and address farmers' needs and constraints. This bottom-up approach was contrasted with the old 'top-down' prescriptive approach to identifying farmers' needs, in which the researchers played the main, and sometimes it must be admitted, the only role.

The FSIPM Project began work in January 1996 and will end in March 2000. In developing its work programme, the project was guided by a Stakeholder Workshop held in July 1996 which brought together the research community, and by numerous consultation meetings with extension staff and farmers during that year.

The project deliberately focused on those parts of Blantyre/Shire Highlands with the highest population levels and smallest landholdings and made a point of including a significant proportion of female-headed households amongst the participating farmers. The food crops targeted by the project (maize, bean, pigeonpea and sweet potato) were those deemed most likely to make a significant contribution to household food security and income.

Projects often outlive the value of the priorities set at their inception. In the case of the FSIPM Project, it is interesting to compare this choice of crops with the priorities set in the Malawi Agricultural and Natural Resources Research Master Plan, published by the National Research Council in September 1999.

It is encouraging to find that in the Master Plan cereals are still seen as the key commodity group, with legumes and oilseeds, and root and tuber crops as third and fifth priority commodities, respectively. Within each commodity group, all the FSIPM Project focus crops are currently listed as either first priority (maize, bean, sweet potato) or second priority (pigeonpea).

The pest management problems which were selected for the initial focus of the project were those which had been highlighted by the research community and farmers as posing the most serious threat to crop production. Pests and diseases are still recognized in the new Research Master Plan as a priority constraint to productivity.

However, declining soil fertility has risen to the top of the production constraint agenda in recent years and I am delighted that this meeting has brought together representatives of most of the significant initiatives within Malawi who are seeking to address what is now perhaps the single most important limitation on smallholder production.

Ladies and gentlemen, three cropping seasons have passed since the inception of the FSIPM Project and once again a representative group of professionally qualified and concerned stakeholders has been convened to discuss, and to find ways of applying, the lessons which have been learned.

Many of us have spent at least part of our professional lives as subject specialists, but this project was unusual within Malawi in seeking to bring to bear a broad range of disciplines from both the natural and the social sciences to help us understand all aspects of the farming system of the target area. To a greater extent than previously, this project (along with others represented here today) has sought to treat farmers as experts in their own right, rather than simply the passive recipients and unquestioning users of the knowledge developed by researchers. During this workshop we will be exposed to some unfamiliar ideas, some of which may run counter to the wisdom that we have received from our teachers. Let us take the opportunity to see what actually happens to our technologies when they are applied under smallholder conditions and learn how farmers themselves judge our efforts on the basis of that performance.

The project still has four months left to run and is trying to involve other stakeholders in shaping the outputs of the project, within the context of other initiatives which are seeking to address common goals. All project findings will be professionally documented and delivered to the Ministry, the British High Commission and other interested stakeholders.

This week's workshop provides an excellent opportunity to identify emerging priorities which will have to be addressed by the research/extension/farmer combine in the opening years of the new millennium. It can also enable us to develop approaches, based on hard practical experience, towards building a relationship of mutual trust between rural people and the research community as we seek to develop a common strategy for the sustainable enhancement of crop production.

I am pleased to be able to tell you that a separate extensive programme of evaluation has been conducted with the project's most important stakeholders – the participating farmers – during the final season of fieldwork. This process has involved meetings between participating farmers and members of the Ministry's Steering Committee for the FSIPM Project and the Technology Clearing Committee.

The farmer evaluation process culminated in a final 1-day workshop and party for about 100 farmers at Bvumbwe Research Station earlier this month, together with the grass roots extension staff from the project area.

At the original Stakeholder Workshop, Dr Harry Potter focused delegates' attention by asking what the FSIPM Project could do which would be of more direct benefit to the farming population of Blantyre/Shire Highlands than simply dividing the total cost of the project by the known population of the Rural Development Project and giving all the money to the farmers! It still does us no harm to have that thought in our minds as we spend this week reviewing progress and looking to the future.

With these few words, Mr Chairman, I now declare this workshop open and I await with keen interest the practical results of the sharing of ideas and development of specific plans which are to take place at this meeting over the next few days.

The role of on-farm participatory research in enhancing rural livelihoods in Malawi

H. L. Potter

Natural Resources Adviser, Department for International Development (DFID), British High Commission, PO Box 30042, Lilongwe, Malawi

Principal Secretary, Dr Daudi, Dr Ritchie, colleagues from Malawi and our visitors from overseas.

I was very happy to accept the invitation to attend this workshop, both as a DFID representative and, as a chance to return, albeit briefly, to my former role as an agronomist involved in research and development in Africa for more than 20 years.

As the DFID Project Officer for the project for the past 3 years or more, I have followed its progress closely as it has attempted to address some of the problems of smallholder farmers in southern Malawi. The partnership between the British and local scientists has gradually developed to the mutual benefit of both. It has moved toward a common understanding of the difficulties faced by farmers and what might be appropriate as interventions, bearing in mind the severe limitations to the resources available to such farmers. The professional team is somewhat unusual for an agricultural project, having a substantial element of the social sciences. This has fitted in well with the growing recognition that rural livelihood improvement depends on more than the traditional agricultural disciplines of agronomy, plant breeding and pest and disease management. The social scientists, both local and from overseas, have been able to apply a 'reality check' to the wilder ideas of the agriculturalists by providing valuable information on the attitudes and perceptions of the farmers. I can think back in my own career to a couple of occasions where such a check would have been helpful at an early stage in development of a technical programme. Failure to fully realize the impact on availability of family labour for weeding coffee, or recommending a 'cut and carry' system for dairy farming in Kenya, proved particularly salutory experiences for me!

DFID believes that this project is an excellent local example of the change in research approach that is now gathering pace world-wide. The smallholder farmer's livelihood does not just depend on crop, or livestock yields, but on a complex set of factors, understanding the interdependence of which requires a wide range of technical disciplines and a good rapport with the farmers. There is a growing recognition that smallholder farmers are not ignorant and extremely conservative. To be able to survive at all in the difficult circumstances of small landholdings, poor soil fertility, lack of investment resources and often unpredictable weather is a challenge which many of us would be hard pushed to meet. The more the smallholder farming systems are examined then the more it becomes obvious that such farmers are continually experimenting, albeit in a way that our biometricians would have difficulty analysing. A major role for researchers is to test how far these individual experiments can be successful on other farms.

The world-wide trend is, therefore, to supplement the traditional discipline-based, or commodity-based research programmes, with a more holistic approach in which a wider range of technical specialists, including those from social sciences, work with farmers. This close contact with farmers inevitably will involve more on-farm work if it is to take account of the real conditions faced by the farmers. In many cases, farmer participation in the design and implementation of such work gives more credibility to the recommendations which might ensue. Credibility is much more difficult to obtain if the work is only carried out by the scientist alone, especially if on a research station.

The implications of this change in approach are far-reaching. Agricultural scientists in many cases will need additional training in techniques for successful interaction with farmers. I know this has already been recognized in Malawi, with courses at Bunda College attempting to meet the challenge. Greater involvement of social scientists – economists and anthropologists, biometricians, especially in the design stage, engineers, ergonomics specialists, and small-business specialists will certainly be needed. This may not mean the establishment of more full-time positions within a national research institution. Such institutions are becoming more streamlined and flexible, with fewer full-time staff and a greater element of part-time expertise in a wider range of disciplines, as they accept the limitations of core budget financing and move towards a research contract-based future. The Department of Agricultural Research and Technical Services in Malawi will move inevitably in this direction. I can assure you that DFID and other donors are in active discussion with the Minister and the Principal Secretary regarding possible partnership in assisting the process. Those who might be affected by such a move would do well to talk to the three Technical Co-operation Officers on the project and their visiting colleagues from the Natural Resources Institute in the UK, to learn first-hand what is involved!

A major implication of the need for increased attention to on-farm work is the cost of such activities. Transport costs are ever-rising and we all know about the growing interest in fieldwork allowances! This will mean that work will have to be given greater scrutiny, both in design and implementation, to assess how high a priority it should have for funding. Researchers in Malawi, as elsewhere, will have to become more skilled in seeking clients for their services, through better investigation of the research market and attention to preparation of properly costed, time-bound proposals. An interdisciplinary approach, clearly involving participation by farmers and extension agents is likely to be more successful in attracting financial support, whether local or from donors. The farmer participation will need to be more than just cosmetic – we have to move away from the sentiment I once heard expressed as "participation is teaching farmers how to listen"!

In the interests of true participation, I, therefore, can take my own hint and close my remarks. I wish you well in your deliberations this week. I only wish that I could attend for the whole week, but I am afraid the demands of the Starter Pack Programme and the DFID involvement in the National Forest Action Programme will not allow for that. I do hope to return for the Friday session, when the discussions reach their climax.

I will be particularly interested to hear what you feel would be appropriate next steps to build on the achievements of the FSIPM Project. I can assure you of DFID's continuing interest in the agricultural sector in Malawi, as part of an overall strategy, shared with the Malawi Government and people, to improve the livelihoods of rural communities.

Groups and projects working in on-farm technology development in Malawi

THE MALAWI–GERMAN PLANT PROTECTION PROJECT

I. Hoeschle-Zeledon

Malawi–German Plant Protection Project, PO Box 2111, Lilongwe, Malawi

The Malawi–German Plant Protection Project (GTZ–MGPPP) is carrying out almost all its research activities on-farm and involves farmers and extensionists; few trials are conducted on-station. On-farm research is carried out on cassava along the lakeshore (at Dwangwa, and Nkata Bay), on cabbage and tomatoes in Ntcheu Rural Development Project (RDP) and on stored maize in Chickwawa RDP.

To make sure that the research activities meet farmers' needs, problem analysis was carried out with farmers and they prioritized the problems.

Several years of on-farm research experience exist for cassava. Pest and disease resistant/tolerant cassava varieties, which are also high yielding, were selected by farmers and multiplied in communal nurseries for further distribution. The palatability and cooking characteristics of the new varieties were not acceptable to farmers initially. However, through blending the flour with flour of the traditional preferred varieties and introducing different methods of cooking, the new resistant varieties are now in great demand. Farmers have been trained in pest and disease identification and were advised to rogue virus-infected plants immediately. Research activities have been limited to one Extension Planning Area (EPA) but will start soon in two more EPAs.

For stored maize protection, integrated pest management (IPM) technologies, such as storage hygiene measures, shelling maize, mudding of stores, use of chemicals, storage in bags, have been developed with farmers. Loss assessments are regularly made in farmers' stores.

The vegetable programme focuses on clubroot and diamondback moth control in cabbage, and red spider mite control in tomatoes. Farmers' traditional knowledge of pest and disease control is included in the screening of possible control options and they are involved in trial planning, data collection and evaluation. All necessary work on the trial plots is done by the farmers with the assistance of extensionists. Training in pest identification and data collection are provided for farmers and extension staff.

The vegetable research programme particularly, faced many problems at the beginning of the project. Farmers were reluctant to participate in the trials due to negative experience gained with other organizations and programmes in the past when, after a short time, researchers either never returned or gave them no feed-back on the findings. They expected immediate solutions to their problems from the researchers because "they are the experts". It was difficult to make both farmers and researchers understand that in research both sides must learn from each other and work as a team. Field assistants had a poor reputation in the villages and farmers did not believe in their commitment. Farmers feared possible losses of their crop due to the project's interventions and they also feared that project and extension staff would claim the yields. Those farmers who finally volunteered in the trials partly abandoned the programme for various reasons, such as family problems, irrigation problems, insufficient assistance by extensionists and researchers, or because the interventions seemed to them to have had little impact.

In the second year, participation was much higher with few farmers dropping out of the trials. Most farmers actively cooperate while others still show little interest. They show particular interest in those trials where chemical pesticides are applied, because they believe those treatments will give the highest yields. More women than men are carrying out trials that employ traditional plant protection measures.

Regular visits of farmer groups to other farmers take place to exchange information. During farmers' field days, farmers explain the trials to larger numbers of invited farmers who are not participating in the trials. The trials have initiated constant discussion in the villages about pest control approaches and even farmers' groups with chairmen have been formed to better organize the trials.

The project works with about 20 farmers in the cabbage programme and 70 farmers in the tomato programme. Because of the intensive assistance required by farmers when participating in the research and the limited resources available to both the extension and project staff, it is not possible to increase the number of farmers at this stage. However, once they have proved acceptable to the project farmers, these technologies can be easily disseminated.

CONCERN UNIVERSAL

J. Mapemba

Concern Universal, PO Box 1535, Blantyre, Malawi

Concern Universal (CU) is a British-based NGO. In Malawi, it has three major programmes among which is the Food Security and Sustainable Livelihood Programme. This programme is based in Dedza and has four projects on household food security and sustainable livelihoods. The major activities carried out under this programme are listed below.

Agricultural diversification

Legume production

CU is promoting legume production by providing seed on loan. The aim is to improve household nutrition and incomes as well as improving soil fertility through nitrogen-fixation. Legumes promoted are bean, groundnut, soyabean, cowpea and Bambara nut. Over 15 000 households are benefiting from this activity. Out of these households, 612 participated in the multiplication of bean and groundnut seed.

Small-scale irrigation and water development

CU is promoting winter cropping through small-scale irrigation. This year, CU provided treadle pumps to two irrigation sites and drilled boreholes to more than 30 villages.

Agroforestry

CU is promoting agroforestry to restore soil fertility which is a major problem.

Livestock production

CU provides livestock on loan including rabbits, goats, sheep, pigs and ducks.

Village extension systems

CU is promoting village extension systems through the establishment of village resource centres and the development of extension packages.

Technologies

CU is promoting technologies, such as permaculture, irrigation, crop storage, seed multiplication, agroforestry and livestock feed formulation.

Small enterprise development

CU is promoting small enterprises by providing loans and training in business management.

Capacity building of communities through training and participatory research

CU conducts participatory research to assist households to identify their own problems and find solutions to these problems. Some of the research work that has been carried out includes:

- constraints on livestock production
- constraints on the adoption of agricultural technologies
- bean and maize variety trials
- participatory rural appraisal in all the villages in which CU is working.

The lessons learnt so far include:

- households experience more problems than the CU is presently addressing
- designs for some variety trials demand more land than a farmer can afford and, therefore, it is difficult to find farmers who are willing to participate in research activities
- households know most of the technologies. However, they do not adopt such technologies because of limiting factors, such as lack of resources (land, labour, planting materials), and low yields, both in crops and livestock. One farmer asked why he did not adopt technologies in crop storage responded by asking: "What am I going to store? I harvest maize enough for three months only!" Another farmer asked why he does not formulate feed for livestock responded by asking: "Should I formulate feed for one chicken? All the animals have been stolen from me!"

CIMMYT

B. Kamanga

CIMMYT-Malawi, PO Box 219, Lilongwe, Malawi

The International Center for the Improvement of Maize and Wheat (CIMMYT) is an international organization with headquarters in Mexico. It has several outreach centres throughout the world. The outreach office for southern Africa is based in Zimbabwe (University of Zimbabwe Farm).

CIMMYT works largely on improving maize and wheat through breeding and production programmes in the world with special interests in smallholder farming. Research is being conducted in various disciplines employing a large number of international and national scientists. CIMMYT activities are grouped into five programmes, one of which is the Natural Resources Group (NRG).

To look into ways of improving productivity and sustainability of maize-based systems, the Australian Centre for International Agricultural Research (ACIAR) and Australian Aid fund the Risk Management Project (RMP) under CIMMYT's NRG programme. The Agricultural Production Systems Research Unit (APSRU) in Australia successfully developed a model called Agricultural Production Simulation Modelling (APSIM). The model is used in the RMP for validation and use in running farmer condition scenarios. The RMP has two components, modelling and farmer participatory research (FPR). The modelling section conducted validation work along with FPR in site characterization. FPR work concentrated on farmer typologies, soil typologies, climatic typologies and livelihood issues of households. The information gained is now being used in agronomic practices in the second year for which farmer scenarios will be identified and appropriate information entered into the model runs. The model results will identify production issues that will be discussed at length with farmers. Modelling and FPR will at this time interface strongly.

The project is currently covering Malawi and Zimbabwe in southern Africa and, depending on the first phase performance, the project will cover other countries in the region. The project was initially funded for 3 years from 1997 to 2000 and is likely to be extended for another 3-year period.

ACTION AID MALAWI

B. Msiska

Action Aid Malawi, PO Box 30735, Lilongwe 3, Malawi

Action Aid's mission is to eradicate poverty by working in partnership with the poor. Its mandate is to co-ordinate all matters concerning issues of food security and natural resources management.

The goal of the Food Security Sector – Smallholder Seed Multiplication and Dissemination Project is to improve household food security of the resource-poor smallholder farmer. Its purpose is to increase availability and accessibility of improved seed and plant materials to resource-poor smallholder farmers.

In response to the 1991/92 drought when farmers failed to produce sufficient food and hence consumed the seed which should have been used for planting in subsequent seasons, Action Aid distributed 13 t of assorted seed types to 1.2 million affected households. From the subsequent crop yields realized from this seed input, it was confirmed that probably the major constraint to smallholder food production was unavailability and inaccessibility of improved seeds.

In 1995/96, Action Aid–Department for International Development (DFID)–Government of Malawi initiated the Smallholder Seed Multiplication and Dissemination Project. The objective of the project was to assist smallholder farmers to multiply and disseminate improved seed types and plant materials of their choice.

Community seed producer groups (SPGs) were formed in four Agricultural Development Divisions (ADDs) in Blantyre, Madunga, Kasungu and Mzuzu. Each SPG comprised about 20 members, both male and female farmers. These groups were asked to select a crop of their preference whose seed would be multiplied. The project distributed a seed supply worth about £2. The SPG multiplied the seed and sold it around the neighbourhood and shared the remaining seed among group members. Proceeds from the seed sales were deposited in a group account to be used as a revolving fund around the community.

Four years after the start the project has achieved the following:

- 543 SPGs have been formed, of which 333 have multiplied 255 000 t grain seed from 26 t, and 210 SPGs have multiplied cassava (11 000 m sticks) and sweet potato plant materials (600 50-kg bags of vines);

- these 543 groups have the capacity to operate and maintain group revolving fund accounts;
- 54% of the target primary beneficiaries (>8000 in total) claim to have experienced food security improvement after participating in the project;
- female farmers, who make up 68% of the participating households, claim to spend less time looking for food since their household food security has improved;
- increased trade for cassava and sweet potato materials.

Some of the constraints experienced are:

- low seed multiplication rate (at a ratio of 1:10 on average) due to the nature of the crops that are being multiplied;
- pests and diseases in the bean seed crop due to excessive rainfall in the last 2–3 years;
- low seed diffusion from the nucleus SPGs to other farmers, especially those more distant from the groups.

In future, the project will focus on:

- empowering the communities to run their own seed multiplication and dissemination programmes and associated activities;
- facilitate community uptake of processing and utilization technologies;
- link the SPGs to effective and efficient marketing systems for seed and crop produce through which they can bargain for favourable market prices.

GTZ-INTEGRATED FOOD SECURITY PROGRAMME (IFSP)

M. M. Kayembe

GTZ-IFSP, PO Box 438, Mulanje, Malawi

IFSP aims to support smallholder farmers in reducing levels of food insecurity and establishing sustainable food security systems. The programme started in January 1999 and will continue for 3 years. The area covered by IFSP is Mthiramanja, Mkanda and Juma in Thuchila and Msikawanjala EPAs in Mulanje. IFSP's work is arranged in seven sectors.

Village planning process sector

Participatory rural appraisals (PRA) are conducted. Before IFSP starts work in any new villages, the PRA team, composed of experienced counterparts in the Ministry of Agriculture and Irrigation and IFSP, hold PRA meetings at all levels within the community. In the meetings they discuss:

- identification and analysis of current problems that hinder development;
- prioritization of problems and possible solutions to such problems;
- presentation of PRA results to other sectors for implementation after approval by the committee composed of members from the communities, government and IFSP.

Agriculture sector

Currently this sector implements the following activities.

Soil conservation

Soil is conserved by activities such as making compost manure, construction of contour ridges using A-frames, and community-based agroforestry nurseries.

Seed multiplication

The sector distributes seeds of maize, pigeonpea, groundnut and soyabean to farmers who have carried out the soil conservation measures mentioned above. The seeds are given on credit to be repaid in kind to the Conservation Area Development Committees. The repaid seed (village seed bank) is given to new members of the same group the following season.

Small-scale irrigation

Irrigation enhances production through a second harvest in the dry season. Crops grown include maize and vegetables on an average 1-ha area of land. The income realized from sales of produce can be used for buying food (maize). Inputs such as treadle pumps, agrochemicals, seeds and fertilizers, etc., are given on credit to be repaid completely after two seasons. IFSP also provides training for farmers.

Poultry production

The programme organizes vaccination campaigns against Newcastle disease, distributes black Australop birds at a subsidized cost and disseminates information on nutrition. The aim is to multiply the birds using the local birds hatchery but distribution will be discontinued because of the unreliable source of supply of chicks.

Fruit tree production

IFSP trains farmers in the techniques of fruit tree production so that they can become commercial producers. Training includes seed collection, nursery establishment and management, budding and grafting, gross margin analysis and market information systems. Four fruit tree nurseries of different fruits are currently set up for training. The programme will subsidize the cost of a single tree per farmer.

Kitchen garden horticulture

The aim is to supplement households' vitamin requirements, especially during the dry season, when vegetables are scarce and if available, expensive. The garden is established close to the house for ease of watering using waste water from the kitchen. IFSP trains farmers and gives them starter packs of seeds and watering cans free of charge.

Health sector

This sector carries out the following activities:

- promotion and dissemination of family planning messages through youth theatre, meetings, training and posters;
- promotion of safe motherhood through training of community-based traditional birth attendants;
- provision of community-based drug boxes in communities far from hospitals; the community buys the drugs from the box kept by trained personnel;
- construction of clinics for the under-5s;
- training the communities to construct clean toilets.

Public works (food for work activities)

This sector distributes food (maize) to communities where food shortages are acute, due to flooding and bad weather. The food is given when the communities have carried out some development work, such as forestation, road construction, etc. Such development work is identified by the communities themselves. IFSP only supplements what the community cannot afford, for example, cement for bridge construction. Currently, communities are managing large community-based forestry nurseries of different trees, both exotic and indigenous.

Water sector

The major activity of this sector is the sinking of boreholes in vulnerable areas where water shortage is an important problem. The vulnerable villages are identified by the communities which provide labour and materials, such as sand and stones, while the programme provides technical training on maintenance. Digging of the holes is done by local trained artisans.

Food processing and storage sector

The main objective is to train men and women farmers in the preparation and processing of some food crops, such as soyabean and pigeonpea. It also trains farmers in how to store cooked and uncooked perishable foodstuffs. The current major activity is the moulding of mud stoves which are economical with firewood during cooking.

Income generating activities sector

This sector works with the existing credit institution, FINCA in Mulanje. IFSP does not intend to become a credit organization and is looking forward to establishing an independent credit institution such as APIP.

Achievements and challenges

So far the programme has had many achievements.

- It has managed to establish community-based farmer groups which deal with land/soil conservation issues.
- Through the public works sector, the road network in the villages has improved enormously. Most river banks have been planted with either exotic or indigenous trees.
- Through the village planning sector, communities have been greatly empowered, evidenced by the strong two-way flow of information.
- More than 9000 households have been given access to improved seeds of maize, pigeonpea, groundnut and soyabean and also planting materials of cassava and sweet potato vines. Demonstrations of various crop varieties have been carried out every year.
- The drinking water problem in the programme area has been greatly reduced due to the sinking of boreholes by IFSP.
- Through small-scale irrigation, farmers are selling large quantities of vegetables and generating income to buy maize.

IFSP faces many challenges.

- Technology adoption is a slow process. Farmers tend to see what other farmers are doing first before they follow.
- Targeting is not an easy task, especially in regard to seed distribution.
- Farmers are generally willing to take up new technologies but they lack facilitation and motivation.
- There have been problems in procuring some inputs, such as pigeonpea seed for distribution.
- The programme has had problems with an unreliable supply of poultry to the point that distribution will discontinue.
- The programme would like to cease handing out free inputs for the establishment of kitchen gardens.

DISCUSSION

A. Orr. An important theme from the opening session is the importance of markets. Dr Potter emphasized the importance of market-led agricultural research. Mr Simtowe mentioned the importance of market incentives for the adoption of legumes to increase soil fertility. Finally, Mr Msiska told us about the need to include marketing aspects (processing and utilization) as components of seed multiplication projects. This theme of markets will get stronger as the workshop proceeds.

J. M. Ritchie. It is interesting to hear from Dr Hoeschle-Zeledon that it is only possible to work in depth with a limited group of farmers in any one season. This has also been our experience in the FSIPM Project. We only work overall, with about 100 farmers, because we have to spend so much time visiting them and discussing with them.

I. H.-Z. To get meaningful data, farmers have to be trained in data collection which requires a lot of time and other resources. Farmers have to be guided throughout the growing season which requires individual visits. Since their plots are often far from passable roads, these visits require a lot of time. Research cannot rely fully on the extensionists since they lack transport and have to go on foot to the farmers which they are reluctant to do unless there are some incentives.

T. D. Mzilahowa. Since farmers were reluctant to participate, how did you overcome the problem of their unwillingness?

I. H.-Z. We developed a working plan with farmers and we made sure that we never failed to visit at the agreed time or to carry out the agreed activities. Regular evaluation meetings and farmers' visits to fellow farmers also helped. Extensionists had to be motivated through special training and convincing them that through the project they could improve their reputation in the villages.

C. R. Riches. What type of model was the Risk Management Project's first-year field work set up to validate?

B. K. The APSIM model, a biophysical model developed in Australia.

M. M. Kayembe. You indicated that it was not within the scope of the Action Aid seed project that planting materials and seed be sold outside the impact area. When farmers produce and want to sell, they want to sell at a higher price. What mechanisms did you put in place to make sure that the planting materials and seeds were sold within the impact area?

B. M. The project was designed to satisfy seed demands within the neighbourhood of the target area. However, farmers were not forced to sell their seed produce within the target area. The project advised groups to record every buyer of seed to facilitate monitoring on how wide the seed was distributed.

H. Potter. The Action Aid project was designed to encourage groups of producers to become sustainable businesses. This led to a conflict between supply of seeds to the local community – at relatively low prices – compared to sale to other programmes or buyers outside the community where prices were higher. To survive as a business the higher price market is preferable. This accords with world-wide experience as examined by the Overseas Development Institute.

D. Coyne. Were cultivars chosen for farmer distribution according to farmer preference?

B. M. Prior to formation of groups, the project conducted a PRA exercise in which communities in the target areas indicated the type of seed crops which were scarce. Groups then selected two crop types in order of priority, and the project supplied seed of the first or second preferred seed type.

J. Lawson-McDowall. Why was there a slow process of diffusion?

B. M. Groups tended to sell their seed crop within the area of operation, particularly to relations and friends. Group workers were very happy and very protective of the seed they multiplied. It gave them social status to be associated with the improved seed types. In general, all the seed crops being multiplied had a low seed multiplication ratio (1:10 on average), hence low production.

V. Saka. Experience has shown that intermediate buyers have intercepted the seed, especially bean, groundnut, pigeonpea, and materials for cassava and sweet potato, that farmers expected to get from source, e.g. Action Aid, the following year. Did you experience these activities in your target areas?

B. M. There were no reported cases of intermediate buyers accessing the seed produced by groups. However, there were a few reported cases where other NGOs bought seed from the groups.

A. J. Sutherland. Can you explain more about why sales of seed to collaborator NGOs was not part of the project's objectives? (This could be regarded as effective dissemination.)

B. M. Action Aid was worried about seed being sold to other NGOs because these NGOs were supplying this seed to communities outside the target area and in the process denying the target communities access to seed which was primarily meant for them.

F. P. Chipungu. A word of caution to NGOs involved in the multiplication and distribution of cassava seed. Fields should be inspected for purity in terms of variety and should be clean in terms of pests and diseases. This will enable the production of quality seeds.

P. W. Kabuluzi. In the roots and tubers multiplication programme, what has been the percentage impact of the produced cuttings and vines over the target number of beneficiaries? What was the measuring system used to determine the total length of cassava sticks and number of bags of sweet potato vines produced from the nurseries?

B. M. The project did not meet its targets in terms of cassava and sweet potato materials produced and supplied to groups. Project staff in collaboration with extension personnel measured each and every cassava stick (usually about 0.5–1.0 m in length) supplied to farmers. Sweet potato vines were supplied in 50-kg bags.

J. M. Ritchie. What varieties of bean were grown in the situation where you describe uptake as falling off? Our experience with 'improved' varieties has been that they do not cope well with smallholder management (e.g. intercropping with maize) and tend to succumb to diseases.

B. M. Action Aid was promoting Napilira, Nasaka, Mkhalira, Kambidzi, Sapatsika and Kalima, obtained from the Bunda College Bean/Cowpea Project and the Chitedze Bean Improvement Programme. Napilira, Mkhalira and Kambidzi were the farmers' preferred choices.

1. Setting the Scene

The FSIPM Project and the smallholder farming system in Blantyre/ Shire Highlands

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ABSTRACT

This paper sets the Farming Systems Integrated Pest Management (FSIPM) Project within the context of the Blantyre/Shire Highlands Rural Development Project (RDP) area and the predominant farming system of the RDP. The main socio-economic, social and biophysical factors affecting farmers are briefly outlined. Biophysical factors include the unimodal rainfall pattern with a pronounced dry season which largely defines where and when specific crops may be grown. Land shortage and declining soil fertility are major factors which together constrain the range of innovations and the levels of yield which farmers can expect from their fields. Among socio-economic factors affecting smallholders are the peri-urban nature of the Blantyre/Shire Highlands with national and international markets within reach. High costs of inputs and lack of access to good quality seeds and credit are major constraints to farmers' productive capacity. Social factors defining relationships within and between households, such as matrilineality, and the close spatial arrangement of related households have a profound effect on farmers' coping strategies and the ways in which new information is acquired and passed on. The original purpose and outputs of the FSIPM Project are described and the processes of consultation and establishment of a crop and pest focus within the work programme are discussed, together with some consideration of the changing context to which the project needed to adapt its work as the project developed.

INTRODUCTION

The Farming Systems Integrated Pest Management (FSIPM) Project began work in January 1996 with the aim of "improving the welfare of poor farm families by reducing on-farm crop losses from pests, weeds and diseases" (BDDCA, 1995). The project is funded by the UK Department for International Development (DFID) and the Government of Malawi and is based at Bvumbwe Research Station, between Limbe and Thyolo. The original logical framework specified that the project would work initially in Blantyre/Shire Highlands, but with the intention of covering all three regions of Malawi in 4 years. This objective was considered over-ambitious by the Stakeholder Workshop (June 1996) (Ritchie, 1996) and the logframe was amended accordingly (Table 1). The project has in fact spent three field seasons in Blantyre/Shire Highlands and has sought to validate crop management technologies within this recommendation domain. In the process a great deal has been learned about the farming system, about pests and about how social aspects of farmers' lives influence their evaluation and potential use of integrated crop management technologies.

During the lifetime of the project, DFID has added a fifth output to the logframe, covering documentation of the farming system, the methods employed by the project and evolution of project philosophy, recommendations for farmers and extension staff and lessons for the donor. This is intended to ensure that all the learning gained by the project is made available to stakeholders, whether farmers, extensionists, researchers or donor representatives and policy-makers. This workshop is itself a part of that documentation process and provides a means of disseminating information on the farming system, methods and approaches to on-farm participatory research, and the performance of specific technologies.

THE FARMING SYSTEM: AN OVERVIEW

The FSIPM Project operates in two extension planning areas (EPAs) in the Shire Highlands Rural Development Project (RDP) in Blantyre Agricultural Development Division (ADD). The RDP has a land area of 450 000 ha.

The Shire Highlands form a plateau of rolling or flat upland plains 600–1200 m above sea level. The climate is warm tropical with rainfall ranging from 600 mm to 1300 mm depending on altitude. Rainfall distribution is unimodal with one continuous wet season during November–April, followed by sporadic showers (*chiperoni*) between May and July and a dry period during July–October. Rainfall diagrams for Matambo Estate, Chiradzulu North (Mombezi) EPA for 1990/91 to 1995/96 and for 1996/97 to 1998/99 (Figures 1 and 2) show that rainfall during the project period was much

Table 1. FSIPM Project: revised project logical framework

Narrative summary	Measurable indicators	Means of verification	Important assumptions
Supergoal 1. Improved incomes for resource-poor farmers.			
Goal 1. Farmers adopt low-cost sustainable integrated pest management (IPM) strategies.	1.1 *X* percentage of farmers in zone adopt by year *y*.	1.1 ADD Monitoring and Evaluation Surveys.	**(Goal to Supergoal)** 1.1 Economic environment remains favourable.
Purpose 1. Local capacity for IPM improved.	1.1 Commodity Teams (CT) incorporate IPM strategies for maize and two other major food crops.	1.1 Department of Agricultural Research and Technical Services (DARTS) annual reports and CT reports.	**(Purpose to Goal)** 1.1 Extension system continues to function effectively.
Outputs 1. Research capacity for farming systems IPM research strengthened.	1.1 At least six Malawian postgraduate scientists trained in IPM by end of project. 1.2 Three seasons on-farm IPM research experience for staff attached to project by end of project. 1.3 Two seasons on-farm IPM research experience for returned graduates by end of project. 1.4 Buildings completed according to contract date.	1.1 Project reports. 1.2 Project reports. 1.3 Project reports. 1.4 Quantity surveyor's reports.	**(Output to Purpose)** 1.1 Suitable staff are identified, assigned to the project, and retained by DARTS. 1.2 Adequate budget. 1.3 Returned graduates remain attached to project. 1.4 Building costs remain stable.
2. IPM strategies suitable for resource-poor farmers developed.	2.1 At least one pest management strategy per crop by end year 2.	2.1 Project reports.	2.1 Stakeholders continue to develop and refine IPM strategies.
3. Improved extension materials prepared and disseminated by both formal and informal extension networks.	3.1 Three packages of extension materials (one per crop for verified pest management strategies) developed by end year 3.	3.1 Project reports and extension materials.	3.1 Informal and formal networks willing and able to co-operate. 3.2 Timely approval of IPM strategies by Technology Clearing House.
4. Project management systems implemented.	4.1 List of management responsibilities. 4.2 Schedule of activities. 4.3 Accounting systems.	4.1 Project document (Annex), job descriptions. 4.2 Work plans, GANTT charts. 4.3 Accounting records.	4.1 Timely financial information available to management.
5. Full documentation and archiving of all project trials data, analysis, recommendations and methodologies used.	Archive of trial and survey data. Recommendations for farmers and extension workers. Record of project methodologies and evolution of project philosophy. 5.4 Descriptions of local farming system characteristics.	5.1 Archive to be updated annually. 5.2 Preliminary materials to be tested during 1998/99 field season. Existing documentation to be supplemented by specific reports during write-up period at end of project. 5.4 as for 5.3.	

Prepared at Stakeholder Workshop (Ritchie, 1996) with fifth output added by DFID Reviews (Hansell *et al.*, 1998).

higher than in the preceding 5 years. This has had significant effects on disease incidence in bean and pigeonpea crops which increases in wet years, and on damage due to termites, which is generally less pronounced in wet years.

The growing season averages 165–195 days in the north, rising to 225 days further south. Soils are mostly deep, well drained and medium textured but generally low in soil carbon and organic matter. The maize ecology of the RDP is

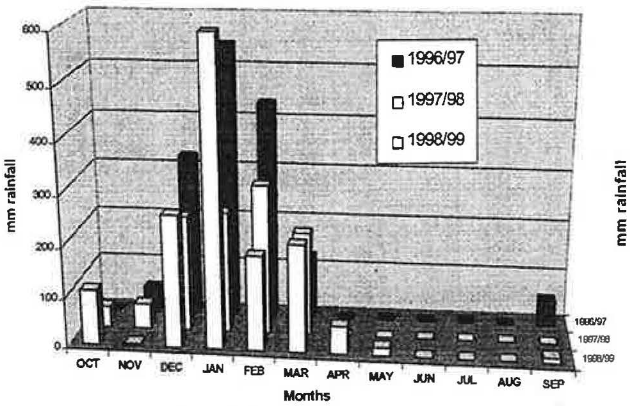

Figure 1. Annual rainfall (October–September) for 3 years (1996/97–1998/99) at Matambo Estate, Mombezi EPA.

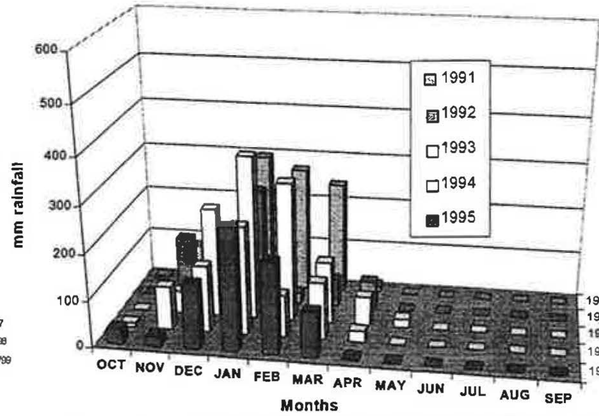

Figure 2. Annual rainfall (October–September) for 5 years (1990/91–1995/96) at Matambo Estate, Mombezi EPA.

representative of 40% of the area planted to maize in Malawi (Heisey and Smale, 1995).

Smallholder agriculture is characterized by small farm size, intensive maize cropping, and low productivity. In 1992, of the 336 000 smallholder households in the RDP, 61% cultivated 0.5 ha or less (GoM, 1996). More than 90% of the arable area is planted to maize. At current productivity levels, the average household is self-sufficient in maize for 7–8 months of the year. These factors help explain the pervasive poverty found among smallholders in this RDP. Of the smallholder households in the RDP, 38% are headed by women, and are generally poorer than average (World Bank, 1996). Adult literacy rates are low, access to safe drinking water is limited, and there is widespread malnutrition evidenced by high rates of wasting among children under 5 years of age (FEWS, 1996).

Both Mombezi and Matapwata EPA, where the project research sites are located, are classified as among the poorest in Malawi (Moriniere *et al.*, 1996). Selection of these EPAs was based on reconnaissance surveys by project staff and discussions with extension personnel which elicited evidence of serious pest problems. Both EPAs are considered representative of the RDP in terms of climate, topography and cropping pattern. They have the highest population density of any EPA in Malawi (285–290 persons/km^2 in 1987). Matapwata was a field site for the Chancellor College Soil Pest Project surveys and trials (1989–92) and Chiradzulu was the site of BLADD's Adaptive Research Team's on-farm trials, 1985–90. The four main villages where the project set up on-farm trials were chosen by a similar process (Ritchie *et al.*, 1996). Presence of pest problems was essential, but additionally, manageable size (100–150 households), presence of a range of land types (*dambo*, upland, hill slope) and convenient all-weather access from Bvumbwe were considered important.

The farming system in Blantyre/Shire Highlands RDP is maize-based with pigeonpea and bean as the main pulse and legume intercrops. Relay planting of bean and field pea is also practised in Matapwata EPA, taking advantage of the longer growing season. Average maize yields are low (836 kg/ha for local varieties and 1765 kg/ha for hybrid semi-flint varieties between 1992 and 1996), reflecting poor soil fertility and low application rates of inorganic fertilizer. Burley tobacco and *dimba* vegetables are the most valuable commercial crops. One third of households in Matapwata EPA grow *dimba* vegetables while in Mombezi about 10% of households grow burley.

Sweet potato is an important cash crop in the southern part of Matapwata EPA. Smallholders enjoy close access to the international tobacco auction floor and the urban markets of Blantyre and Limbe. Agriculture is strongly orientated towards the market and crops grown for household consumption are also widely sold. Two presentations in this workshop will specifically address the problems of smallholders in relation to markets: Orr *et al.* (p. 279) will illustrate how the markets for pigeonpea, bean and sweet potato can be used to provide economic incentives for the adoption of IPM strategies. Jones *et al.* (p. 150) will focus on improving poor farmers' access to technologies and markets for pigeonpea.

CROPPING CALENDAR

The crop calendar (Figure 3) illustrates the complexity of farmers' crop management in this rain-fed farming system. Crop scheduling revolves around maize, which is planted in late November and harvested when fully mature in early May. Four points are highlighted.

Harvest dates for bean and pigeonpea vary according to farmers' choice of crop variety. Farmers prefer varieties with different field durations in order to extend the period when these crops may be eaten fresh.

Relay planting (*mbwera*) of bean, field pea and sweet potato occurs in mid-March. The yield of the relay bean crop depends on rainfall during May–June, and is particularly critical for long duration bean varieties.

Sweet potato is usually planted in February, not November, after farmers have completed the second weeding of maize.

Crop	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Land type: *munda* (rain-fed cultivation)												
Maize												
Bean Kaulesi Chimbamba												
Pigeonpea **Local** **ICP 9145** **Chilinga**												
Burley tobacco												
Land type: *dambo* (seasonally flooded valley bottoms)												
Field pea												
Sweet potato **First crop** **Second crop**												
Landtype: *dimba* (residual moisture cultivation)												
Tomato												
Cabbage												
Rape												
Mustard												
Maize												
Matapwata rainfall 1998/99 (mm)	**63**	284	**386**	**219**	**346**	**278**	**14**	**46**	**45**	**0**	**0**	**13**

Figure 3. Crop calendar at FSIPM Project research sites, Blantyre/Shire Highlands RDP.

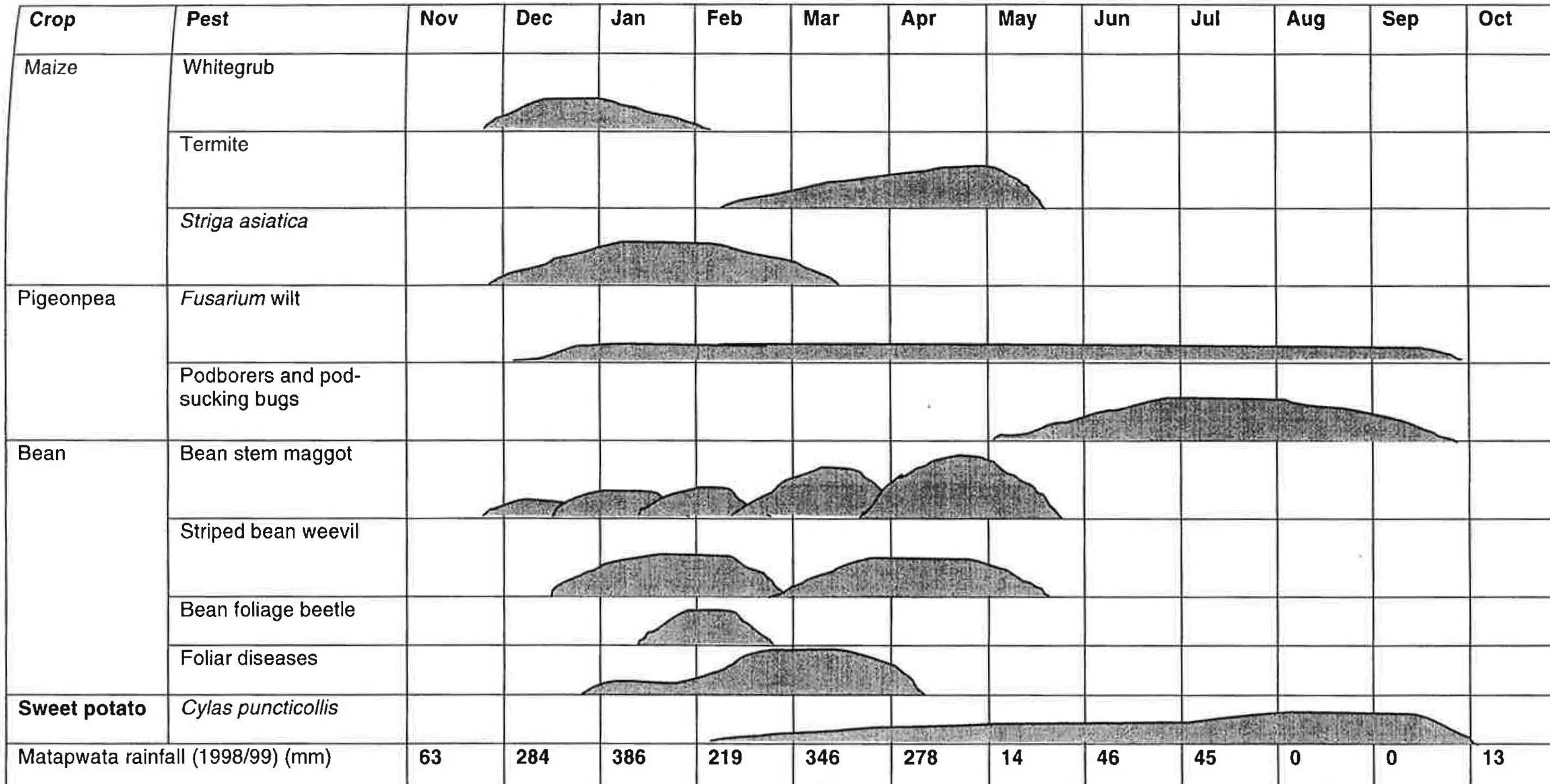

Figure 4. Crop calendar for foodcrop pests and diseases, FSIPM Project research sites, Blantyre/Shire Highlands RDP.

Dimba crops are chiefly grown in the dry season, when pressure from pests and diseases is lower. However, farmers will plant tomato, rape and mustard to provide cash income to buy maize during the hungry period between November and late March, before green maize becomes available.

Target pests of food crops in the region were identified through extensive field surveys by the Overseas Development Administration (ODA)-funded Chancellor College Soil Pest Project, in 1990–92. These showed termite, whitegrub and *Striga asiatica* as the major field pests of maize, bean stem maggot (*Ophiomyia* spp.) and *Ootheca* spp. as major pests of bean, and *Fusarium* wilt as the major pest of pigeonpea (Figure 4) (Munthali *et al.*, 1993; Hillocks *et al.*, 1996). These rankings were confirmed by a Stakeholder Workshop with Malawian crop protection professionals (Ritchie, 1996) and by diagnostic surveys using participatory techniques in four villages in Mombezi and Matapwata EPAs (Orr *et al.*, 1997).

SOCIAL ORGANIZATION IN SOUTHERN MALAWI

Researchers and practitioners now understand that pest management cannot be considered in isolation from the farming system as a whole. However, the work of the FSIPM Project has made it clear that the farming system must be viewed as a component of the broader set of activities that make up peoples' livelihood strategies. For most resource-poor smallholders in southern Malawi, farming is only part of the way that they make a living. Other activities that contribute to their livelihood may include marketing agricultural produce in urban areas, casual agricultural labour, making handicrafts, making bricks, collecting and selling firewood and so on.

The success that a farmer can have in this range of activities is influenced by many factors. Chief amongst these is his or her access to financial, physical and environmental capital and to human capital resources such as training, education or good health care. Access to any type of capital is mediated by a series of structures and processes, such as the rules of lending institutions, government policy on fertilizer pricing, patterns of inheritance or the responsibilities attributed to men as opposed to those for women. A final type of capital, only recently described as such, is social capital. The concept of social capital captures how membership of groups (such as extended families or churches) or networks (such as regular clients at a market) can facilitate or deliver resources that would otherwise be unavailable. Another way to view social capital is in terms of the claims one is entitled to make on other people in pursuit of one's livelihood.

If a farmer is seen as a "central node in a series of intersecting and overlapping systems of relations and influences that include household, family, neighbourhood, regional market organization, etc." then it is much easier to see how these connections "influence patterns of access to key resources (land, labour, other inputs, cash, etc.) and to information" (Peters, 1999).

To this end, a brief description is provided below of the basic structure of social organization in southern Malawi. This structure could also be described as the social organization of production.

Southern Malawi is made up principally of matrilineal societies. This means that land passes through the mother's line and is normally transferred to female heirs. Women are, therefore, the owners of the land with all this implies. A husband usually moves to his wife's village upon marriage. While husband and wife share much agricultural decision-making and labour, they often pursue other income-generating activities where they may both pool or keep separate their working capital or part of the profits. Ideally, husbands are expected to provide the larger amounts of cash needed for purchases like fertilizer or for school fees or hospital treatment while wives concentrate on smaller purchases of foodstuffs or inputs.

Although husbands are formally said to be the head of the household, it appears that many decisions about farming are made together and after discussion. Approximately one third of all households in Malawi are female-headed. This means that there is no adult male and that the woman who heads the household is divorced, widowed or her husband is away for more than 6 months of the year. Some commentators prefer to use the term 'joint' for 'male-headed' households. This captures the importance for an agricultural project of ensuring that its work includes both male and female farmers and a variety of household situations. Without this representativeness, it would not be possible to see if interventions are suitable for the variety of household types found amongst the resource-poor.

Other kinship links or neighbourhood may be as important as the marriage bond. Matrilineal kin, usually a mother and her daughters, live close by each other in a cluster of households known as an *mbumba*. Small gifts of maize, vegetables, fruit and matches, for example, or offers of first refusal on paid labour and small cash gifts or loans flow between these households make a significant difference to peoples' ability to 'get by'. Similarly, related or neighbouring *mbumbas* are often involved in long-standing relationships of mutual benefit. Information, for example, about new varieties, flows most freely between these groups of related or neighbouring households. The issue of information flows is dealt with in more detail by Lawson-McDowall *et al.* (p. 138).

All these relationships will have a role in enhancing or impeding the ability of an individual farmer "to juggle multiple activities, patterns of labour allocation and the trade-offs among the multiple, often competing, activities and their outcomes" (Peters, 1999). Only by being sensitive to the complexity of rural livelihoods in their social, economic and cultural context, can a project promoting interventions concerned with as singular an aspect as pest management hope to succeed. The process by which the project has sought to understand and adapt to farmers' anxieties and expectations, rooted in their particular historical experience of external intervention, is the subject of a further presentation (Lawson-McDowall, p. 21).

CHARACTERIZATION OF HOUSEHOLD TYPES

Tentative recommendation domains for IPM strategies were identified through cluster analysis (Orr and Jere, 1999). Based on a range of socio-economic and production variables, five distinct household types were identified at our research sites:

- *dimba* households producing both maize and high-value vegetables;
- burley tobacco households which do not produce vegetables but produce enough maize to be reasonably food-secure;
- stable male-headed households producing neither burley nor vegetables, but with enough maize to be reasonably food-secure;
- stable female-headed households producing neither burley nor vegetables, but producing enough maize to be reasonably food-secure; and
- vulnerable households producing neither burley nor vegetables and without enough maize to be food-secure.

Differences in terms of crop combinations, food security and fertilizer use suggest that IPM strategies for food crops will not be equally appropriate for all five types of household. Of 20 IPM strategies tested in the 1996/97 season, 13 (65%) were judged to be equally appropriate for all households. However, IPM strategies that required extra cash investment (e.g. fertilizer for *Striga*, chemical seed dressing) or increased labour requirements (e.g. hand-pulling *Striga*, extra weeding) were judged to be problematic for vulnerable households and for *dimba* households where labour was required for vegetable production.

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DISCUSSION

V. W. Saka. Did the farmers in the project area mention infrastructure, i.e. roads and bridges, as major constraints to crop production?

J. M. R. No.

P. W. Kabuluzi. During project design and appraisal is it not possible to include a component of construction works (e.g. bridges and roads) in the selected rural areas if the main objective of the project is to assist the smallholder farmers to accept the developed technologies without any obstacles?

J. M. R. Normally within the scope of a natural resources project, donors would not wish to enter into a programme to upgrade rural roads. That is more appropriate to a more general rural development project.

C. T. Kisyombe. On the list of common beans presented in the paper you do not mention foliar diseases, why is that?

J. M. R. In this general overview figure there is a general heading for foliar diseases. The specific diseases change in severity from year to year (e.g. *Ascochyta* one year and common bacterial blight the next).

D. Coyne. How did the project account for pest problems farmers are unable to identify or appreciate?

J. M. R. Some symptoms are recognized by farmers although they do not identify the causal agent (e.g. *Fusarium* wilt and bean stem maggot which are both described as wilting by farmers).

A. Polaszek. I was surprised that for neither sorghum nor maize were stem borers recognized by farmers as being a production constraint, especially given the importance of *Busseola fusca* and *Chilo partellus* on maize in the region.

J. M. R. Farmers do not lose many maize plants to stem borers compared to whitegrubs and termites. We monitored deaths due to stem borers in every season.

Whose agenda? The evolution of the FSIPM Project to accommodate scientists' and farmers' interests and needs

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ABSTRACT

This paper attempts to explain why the Farming Systems Integrated Pest Management (FSIPM) Project as originally designed proved not to be appropriate for the farmers targeted, and describes how the project changed its focus and methods in response to farmers' requirements. Farmer–researcher interactions are discussed in the context of Malawi's specific history: a highly top-down agricultural extension and research bureaucracy, an authoritarian socio-political structure, and experiences of land expropriation and of private and state controls. An exploration is made of the uneasy relationship between the project research design and the requirements of farmer livelihoods, for example, the single purpose of a scientist's experimental plot and the multiple and contingent demands on farmers' fields. The experimental plot is only a small (if significant, because of the interest of influential outsiders) part of farmers' multiple strategies in cropping and income generation. Means of reconciling the tension between the participatory and experimental modes are explored. How can farmers make scientists their clients, and how can scientists carry out on-farm experiments? The combination of a plot each for researcher and farmer is offered as a compromise solution.

INTRODUCTION

The purpose of this paper is to track how the Farming Systems Integrated Pest Management (FSIPM) Project evolved to meet farmers' and scientists' needs and interests, and to describe how, over the three agricultural seasons of its implementation, the project has behaved as a 'process' project rather than a blueprint project. The project's precise outputs and objectives, and how to achieve them within the overall objectives, have been revised and developed as the project proceeded. This has happened through the identification of technical difficulties with the original project design, and through taking note of what the farmer participants had to say about the trials.

We start with a brief summary of the technical reasons why the project as designed proved inappropriate for the farmers targeted. In the following section an attempt is made to place farmer–researcher interactions in the context of Malawi's specific history of top-down and authoritarian interactions between state representatives and ordinary villagers. This is believed to account (in part) for widespread suspicions among the farmers about the intentions of the project. The specific experience of development intervention is described to show that the context and style of the FSIPM Project were different to anything that had gone before.

However, difficulties in the design and management of the plots run deeper than mistakes about appropriate content or layout, and have implications for any attempt at carrying out research with farmers. Throughout the lifetime of the FSIPM Project there has been a tension between the needs of the scientists on the project to carry out rigorous research, and the participating farmers' primary interest in enhancing their food or income security. Such conflicting agendas have created tensions focused on the running of the research plots.

Similarly, the experimental mode of the researchers (their need to know) has come into conflict with the participatory mode (the right of the farmers to direct the content of the research trials) which it was intended the project should adopt. The two-plot arrangement of the final year has been a compromise solution to this problem. These challenges, and the difficulties of participatory experimental work in a food-insecure context, are discussed in the final two sections of the paper. It is argued that any project is inserted into a set of ongoing social, economic and political processes, and that these will influence the direction and success of the work undertaken.

PROBLEMS IN PROJECT DESIGN IDENTIFIED AT THE END OF YEAR 1

By the end of the first year, it was clear that it was necessary to rethink several key aspects of the project design and content. This section provides a brief summary of project thinking about objectives and methods at this stage, taken from Orr and Jere (1997).

Just as farmers had told us, the major constraint on maize yields was not crop losses from pests, but low soil fertility. Lack of fertilizer and unusually heavy rains in 1996/97 had resulted in very low yields. Farmers had lost interest in the plots, realizing there would be little return on their labour. Contrary to assumptions, there was no ready-made menu of IPM strategies available for smallholders. Nor did the normal economic incentive for the adoption of IPM, saving cash spent on pesticides, apply to maize, bean or pigeonpea.

Farmers' participation was limited by the complex design of the on-farm trials, and their lack of scientific knowledge of the biology of pests, such as the bean stem maggot or *Striga*. Farmers also rejected labour-intensive cultural IPM strategies such as mulching or earthing-up. Unfortunately, farmer-developed pest management strategies turned out to be few and localized.

Before discussing in detail how the project responded to these problems, we look at the project from the perspective of the trial participants.

INTO WHAT CONTEXT WAS THE PROJECT INSERTED?

This section draws heavily on a study carried out in 1998 specifically to investigate farmers' suspicions and expectations regarding the project. This research also aimed to understand better the context regarding attitudes to development interventions into which the project had been introduced, and to identify barriers to farmer understanding (Lawson-McDowall *et al.*, 1999b).

An investigation into farmers' expectations of the project showed that suspicions of our intentions were more widespread and serious than had been thought. Just over half of the participating farmers interviewed (31 of 55) told us that their expectations were broadly positive from the start, and that they hoped to see bumper harvests and to receive free inputs. However, nine farmers said they feared that their land would be stolen. When we asked what other villagers were saying, 44 of 55 respondents mentioned rumours that we were planning to steal their land and resettle the owners; that village chiefs were collaborating to sell their people to the Chinese; or that there might be a return of forced labour (*thangata*).

While these fears have to be interpreted against the real historical experience of land expropriation and labour control systems in the colonial period and thereafter in the Shire Highlands, this 'litany of fears' is, it appears, well known to researchers in Malawi. Dr Pauline Peters argues that these suspicions are best understood as conventional ways of expressing fears about the intentions of outsiders (and not just foreigners):

> "In modern terminology, these are discourses of discontent. The real historical experience of past groups has been captured in dramatic icons of hardship and cruelty in much the same way that any drought in this region tends to be likened to 'the 1949 famine'. In short, the suspicions can be seen as both recalling the real experience of past generations that continues to be retold to new generations, and as the conventional or accepted modes of expressing fear in a way that does not directly accuse the specific incoming strangers."
>
> (Peters, 1999)

However, it also became clear from these interviews that the FSIPM Project was very novel in purpose and style for all four villages. The main interventions to date had been focused on maize and tobacco clubs (targeting the better-off farmers), or visits by health visitors to advise on improvements in hygiene. Other interventions, cited by only a few respondents, appear to have had a limited impact. There had been little history of success with agricultural interventions in particular: about 65% had failed (due to defaulting, lack of relevance to farmers, poor implementation and so on).

These findings are supported by an earlier project study of how farmers learnt about agricultural innovation. Only those farmers who were members of clubs had contact with their local extension officers, and the block extension system with demonstration plots was largely moribund (Lawson-McDowall *et al.*, 1999a).

The research also showed that the style of interventions had historically been top-down and authoritarian, and targeted the better-off farmer. The agricultural extension and research bureaucracy carried out both basic and adaptive research on-station. Although there were attempts to modify this approach through, for example, the Adaptive Research Teams, the model of research and extension meant that technology developed off-farm was to be transferred to farmers.

These findings show that farmers had much less context in which to place the project and its objectives than had been anticipated. Previous research had been extractive, whereas the FSIPM Project, with its 'participatory hat', aimed to understand villagers' criteria and to ensure that technologies were evaluated according to farmers' preferences rather than researchers'.

On-farm research was also new. None of the participating villagers had previously been asked to take part in technology testing or evaluation in their own fields, and very few had seen demonstration plots elsewhere. Finally, the notion that experimentation aimed at fitting in with existing farming systems, rather than demonstrating the best practice possible, was previously unknown.

All this means that the farmers taking part in the trials were being asked to make major conceptual reversals in the way that they viewed influential outsiders and representatives of the state bureaucracy. In their dealings with the trials and the project personnel, farmers were asked to comment honestly and freely on any aspect of the trial. Historically, open criticism such as this might well have put individuals at risk.

Farmers were being asked to assess and, if necessary, criticize technologies. Previously, where they had interacted with extension officers, this had been on the basis that the officer was the expert and provider of new and improved technologies, while the farmer was backward in his or her practices and in need of guidance. In comparison, the philosophy behind the FSIPM Project was that the farmer was the ultimate customer and thus the judge of these technologies (this is not to claim that this philosophy always or even frequently dominated practice, but it has strongly influenced the evolution of the project).

CONFLICTING AGENDAS: RESEARCH VERSUS LIVELIHOODS, PARTICIPATION VERSUS EXPERIMENTATION

Having outlined some important features of the context into which the FSIPM Project was introduced, we now explore some fundamental contradictions that appeared to exist between the needs of farmers and the requirements of researchers aiming at hard scientific data collection through on-farm research. Firstly, the demands of research are compared with the way that farmers in a declining farming system such as that of southern Malawi have to "juggle multiple strategies in cropping and income" (Peters, 1999). Secondly, an examination is made of the tensions that may lie between working in a participatory as opposed to an experimental mode. Finally, the project's development of the *kanthu nkako* plots alongside the research plots is put forward as a possible compromise, and the advantages and disadvantages of this approach are discussed.

Research versus livelihoods?

Farming one element in a set of livelihood strategies

The first task is to define what is meant by 'livelihood'.

> "A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living."
>
> (Carney, 1998)

The idea of a livelihood is married with the idea of sustainability in much recent development thinking. So, to complete the quote

> "A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base."
>
> (Carney, 1998)

Farming contributes different proportions of income according to a household's overall package of livelihood strategies. Some so-called 'farmers' earn a greater part of their income from handicrafts, marketing or off-farm labour. So a project such as the FSIPM should, whatever the degree of targeting or self-selection, expect to find gradations of engagement among trial participants. For example, we know of households where a wife or mother spends most of her time on marketing and leaves most agricultural work to teenage children or hired labour, because marketing is a more successful and reliable form of income. This has led to problems for the project trials because teenage children have failed to understand their parent's instructions, or have not bothered to do the work required on the parent's behalf.

The research plot may be only a small part of an individual's or household's resources, and may not have a high priority when compared with other activities or assets. Furthermore, some individuals are more interested, knowledgeable and skilful farmers than others and will engage more enthusiastically with the aims of the project.

However, for the researcher, the trial plots are the foundation stone of the project's research. Without the trials there is no research, there are no results and nothing is learnt. This may result in tunnel vision on the part of the researcher, while farmers are reluctant to explain why they are not particularly interested in the plots.

Maximization of short-term gains

Resource-poor farmers, in the experience of the project, hope to maximize material gains from the project and take a short-term perspective on the results. This means that many farmers, if a crop is poor, will not persist with the crop but seek to compensate for this lost income and capital. This may mean uprooting the crop and planting something else, or abandoning the field and looking for casual agricultural employment instead. Farmers do carry out experiments but are conceptually and practically unable to apply the rigour of research scientists. Furthermore, farmers frequently abandon what looks to be unsuccessful so that they do not waste resources.

Salvaging harvests versus learning from plots

By contrast, it is crucial for researchers to persist with trials until a high level of damage has been reached. Scientists and statisticians think long and hard about the design of trials: which issues or variables are to be examined, the size of plot, the type of location, how to demarcate the plot, the need to measure soil and moisture content or how to eliminate border effects. Every variable must be replicated a sufficient number of times for the statistical results to be valid. Controls must be set up. Criteria, indicators and a time-scale for monitoring must be agreed and a systematic procedure established. The scientists' aim is to think out in advance all the important aspects of the trial. This means that anything that interferes with the trials following their planned course is potentially disastrous. In participatory on-farm research, as a result, scientists (including FSIPM Project researchers) often express frustration when they see farmers failing to honour the 'contract' that they have with researchers about the management of the trials.

However successful the technologies being tested in a trial, the need for controls guarantees some level of failure within a set of research plots. This has been hard for farmers to understand. Consequently, for example, a significant number of farmers who feared that there would be a reduced yield in half of their plots if they were not banked, went ahead and banked the plots. This made it impossible for researchers to compare the with and without effect of banking on termites. Researchers are also able to take a longer-term view. Trials have to be replicated over several seasons to verify a technology or explore its adaptive potential. Resource-poor farmers may be compared to patients in the trial of a new drug: where a drug appears to work, there is frequently pressure to administer it to those who were receiving placebos rather than continue the trial as it was established. Poor farmers need benefits in the short term.

Researchers want to model poverty, farmers want access to the wealth of the project

Trial participants have seen that the project has access to a wide range of resources (seeds, fertilizer, vehicles, foreign employees, etc.). It is natural that farmers should hope to obtain some share of this wealth, in particular through access to decent quantities of good quality inputs. Farmers also expect to see research station associates promoting the best practice available; so, for example, FSIPM Project staff have often been asked why researchers have not used pesticides or double applications of fertilizer.

The desire of farmers to see really good farming taking place on their plots has contradicted the need of researchers to generate results applicable to the local farming system. To this end, the FSIPM Project researchers have tried to follow a low-input model. This is why, in the first year, no inorganic fertilizer was put on the plots – many farmers cannot afford to apply fertilizer.

In many ways the problem is one of mutual misperception. Farmers have ideas about how agricultural science works – ideas that many researchers working on problems experienced in low external-input, diverse and risk-prone environments are seeking to change. The researchers' direction of change is towards working within the constraints faced by farmers, and working with farmers to identify ways of removing these constraints. Farmers, on the other hand, hope that agricultural professionals will bring solutions to their problems from outside their impoverished farming system. Researchers are often unable to appreciate how much farmers need the resources that they are providing.

Some farmers have taken the project's goals on board and enjoy working with the team. For others, it is a useful if minor contribution to income, but not one for which they can spare much time or energy. For another group, it is a frustration that their needs cannot be met more easily through their contact with a resource-rich project. This variation in engagement with project objectives must be seen in the context of declining food security and farmers' knowledge that the project has a limited life span.

Experimental mode versus participation

The FSIPM Project was designed as a participatory project. Participation may be defined as:

> "...a process by which people take an active and influential hand in shaping decisions that affect their lives. Popular participation may involve difficult and long processes but brings many benefits: the contribution of local knowledge [and] an increased chance of objectives and outputs being relevant to perceived needs..."
>
> (ODA, 1995)

Participation should ultimately empower individuals or groups to "initiate action on their own or negotiate with more powerful actors". Participation should therefore benefit all the stakeholders in a project, as the technical aims of the project should be achieved more efficiently if participants are empowered to seek solutions to their problems. In practice, however, participation may contradict the need of a project to run scientifically valid trials.

From the project's perspective, participation required that farmers taking part in the trials were prepared to communicate openly with us about the management and the results of the trials. Yet where problems arose with trial management, farmers avoided confrontation, and it has often been hard to discover the true reasons why farmers did not do something they had been asked to do and to which they had agreed. In interviews with farmers during both monitoring and the research on farmers' suspicions, project staff often felt that the responses they were getting were bland and that some farmers did not say what they really thought. We had assured participants that we really valued their opinions and that we needed them to help us evaluate the results. We emphasized that their comments would not be individually attributed. We also explained that a large number of participating farmers were being asked the same questions to help us understand the larger picture.

Did farmers believe us? Should they have believed us – given how brief our acquaintance had been? Questionnaires to garner opinion are a new phenomenon and are not well understood. Open feedback of problems to the authorities has not been encouraged in the past. Similarly, criticism of the work of high-status outsiders and government officials – to their faces – runs counter to cultural norms of respect, humility and the obligation to avoid open confrontation. Negative views and opinions came indirectly at first, through relatives teasing participants in front of team members or in reports of what others were saying. (The exception that proves this rule is fertilizer – low fertility and high fertilizer prices combined to make farmers vocal on the subject of their need for fertilizer or for the "correct" mode of application.)

However, from the researchers' perspective it was crucial that farmers should give their honest opinions of technologies and trial design. Without this feedback researchers were working in the dark, not knowing if they were fitting their work with farmers' preferences or not.

Importantly, it is hard, certainly in the early stages of the project, to see where the incentives might lie for farmers to offer unfavourable opinions. Here was a project that, while it was not dealing with low fertility (the most important problem facing farmers), was handing out free inputs and promising to compensate farmers for low yields if they occurred. Given that project staff seemed determined to persist with technologies and activities, the objective of which was unclear to many farmers, why risk incurring trouble by criticizing? This problem would have been avoided if farmers had a greater sense of ownership of the trials, and in particular if the trials had been focused on a problem identified by farmers themselves as one of their most serious problems.

Participation was also impeded, particularly in the first year (although much less in succeeding years) by the extent to which farmers understood the purpose and content of the trials. Monitoring and the work on farmers' expectations showed that farmers best understood the whitegrub, termite and *Striga* trials. This fits experience elsewhere in pest management research. Participants understand the purpose of the trials where the pest is visible, is considered a serious problem, and either the treatment is easy to understand or training is provided on pest or disease biology. Where the pest or disease was much less visible and possibly less serious, and the treatment less intuitively obvious, as with pigeonpea wilt or bean stem maggot, the purpose appears to have been grasped only by a minority. It should also be stressed that where most farmers had little or no knowledge of the pest or disease or their effects, they would not have been looking for treatments. These findings suggest that training or education about pest or disease biology is required where a treatment or pest is not visible but is important.

From the agricultural researchers' point of view, the seriousness of a pest or disease and the availability of potential treatments have been the main factors in deciding which problem to target. On-farm research with farmers forces researchers to look again at their treatments, trial design, and the need for farmer education, in order to ensure that farmers are able and want to be involved in monitoring and evaluating this work.

RECONCILING AGENDAS?

How has the project tried to deal with these differences in agenda and move towards a more participatory mode without sacrificing the need for scientific rigour?

Successful plots and soil fertility

The FSIPM Project has addressed this issue on a range of fronts. While keeping pest management issues as the focus of the trials, it has been accepted that soil fertility is the priority for farmers. Hence work began on green manures and on the timing of fertilizer applications. Since the first year, we have tried to avoid having plots that look like miserable failures. This has meant including fertilizer in the pack and having technical team members visit farmers where plots are being neglected to find out what has gone wrong, or providing labour if this is due to illness or other unavoidable problems.

Simpler plots

Most importantly, the trials have been simplified year by year as project members sought to include farmers in the design process, to respond to their criticisms and to ensure that the experiment was relevant to farmers' needs and interests. The complex first-season incomplete factorial design with a fractional replicate, with one plot in each of the 64 farms as the experimental unit, was abandoned in the second year. Evaluation findings were taken on board so that the number of treatments per crop was reduced, and treatments rejected by farmers (such as labour-intensive activities) were left out. The final focus was on varietal resistance, seed dressing and some cultural practices that fitted with farmers' pre-existing work patterns. The research plots were divided into four sub-plots so that most of the treatments were visible to each farmer. This meant that the data required for scientific analysis could still be collected, but that farmers could see what was happening on the plots and give us their views.

Enhanced participation

These adjustments have been possible because more time has been spent talking to and working alongside farmers, and on reflecting on the methods we were using. We have also tried hard to observe local cultural norms in order to make our relationship more like that of collaborators; so, for example, we offer food and drink at field days, and assistance where appropriate, such as on the unfortunate occasions of funerals of trial participants.

In this way we have been able to ensure that the research was, as far as possible, oriented towards technologies that farmers required, for example, legumes that were early maturing as well as pest- or disease-resistant.

By the final year of the trials, farmers were invited to meet with project staff to agree a programme for the implementation of the trials. A training consultancy on Participatory Approaches in September 1998, by Dr Alistair Sutherland of the Natural Resources Institute, considerably strengthened the project's methodology in the final year. Participants were consulted about the varieties that would be planted (considerable information had already been collected on this in the previous monitoring round), and there were negotiations about which activities required the presence of both farmers and researchers, or who could represent the farmer if s/he were absent on a particular day.

Institutionalization of participatory processes

These joint activities were then included in monitoring checklists so that technical team members recorded any relevant details about the meeting: who came, what the farmer said, or whether there were any problems. This may appear a very formal procedure for enhancing participation, but the experience of the FSIPM Project is that participation by farmers must be a planned and monitored activity. Technical officers are used to working to very tight timetables and to collecting precise data sets, often in a mechanical fashion. They, therefore, needed to be given precise aims for each encounter with farmers. Such institutionalization has raised the profile and status of the task.

Sharing information and reinforcing understanding

Networking activities and visitors to the on-farm trials also seem to have helped convince farmers that the project takes their contribution and the trials on the plot very seriously.

Field days and monitoring exercises have been used more and more to encourage farmers to present and develop their understanding of the content and purpose of the trials. For example, in monitoring we asked farmers to describe the trial on each plot and where s/he was not clear, we explained again. Training on aspects of pest and disease biology, or on processing or marketing related to the crops, has also been offered. These activities have motivated farmers and researchers alike by offering new perspectives on the trials or through visitors' appreciation of the project work.

Final-year innovations: the *kanthu nkako* plots

There were two other innovations designed to bring farmers' and researchers' interests closer together in the final year of the trials: the farmers' observation plots (*kanthu nkako*) and the specialist pest groups. Having two trial plots, one designed by researchers, the other by farmers, both managed by farmers, provided solutions to a range of substantive and methodological problems. The project was committed to having farmer-designed and managed trials in the final year, but biophysical data (damage levels, yield measurements) were still required for some technologies for a further year. (Seasonal variation, both climatically and in levels of infestation and infection, means that 3 years' data are normally required if a technology is to be passed by the Technology Review Committee of the Department of Agricultural Research and Technical Services.) A plot for each resolved this dilemma.

The observation plots also met farmers' expressed needs. Many had asked, through meetings and monitoring, for the trials to take place on a larger area and to have more varieties to try out. Farmers were given the same varieties as on the research plots and some new varieties to experiment with. The project asked only that the *kanthu nkako* plots should be close to the research plot for comparative purposes, and that at the beginning farmers should use the labels provided so that we could map the location of the different varieties.

It had been expected that farmers would give similar information about the *kanthu nkako* plots to that about the research plots. To our surprise, farmers talked much more about varietal differences and much less about the layout of the plot than when discussing the research plots. (This finding is discussed in detail in a review of the project's monitoring activities; Lawson-McDowall *et al.*, 1999c.) The double layout also enabled us to compare design and management, and to collect more information on farmers' practices.

Specialist pest groups

The final innovation in the last season was to form specialist pest groups. Following through the logic that some pest management strategies are only economically rational where pest damage levels are high, we aimed to identify farmers with specific problems of whitegrub or termite. This approach had been taken from the start with the *Striga* trials. While the success of the experiment has been mixed due to patchiness of results, and has been reported upon elsewhere, we would argue that the approach is sound. Both farmers and researchers are able to concentrate on a single pest, and farmers' monitoring feedback has been much more focused than previously.

CONCLUSIONS

A critic might suggest that a project which was more appropriate from the beginning, for example, one which had identified the most serious problem with clients and for which there were a range of viable technologies to try, would not face the problems encountered by the FSIPM Project. Unfortunately, carrying out research on-farm is more than identifying a problem and technologies, as we have discovered.

Firstly, any project enters into a particular context. People in rural areas live in a world of economic constraints and possibilities, in a network of friends and kin, have a preformed, if changing, socio-political culture, and expectations and fears about what outsiders may bring. It will take time and work to build up a relationship with farmers (or any other group) so that researchers and farmers are able to negotiate honestly about what they really hope to gain from a project.

Secondly, however carefully tailored to local needs and knowledge, conflicting agendas are all too likely. The research work (and the capacity building that should result) may only play a small part in an individual's livelihood strategies, whereas it is the sole justification for the project. Although farmers do carry out experiments, the fixed parameters of scientific research are alien to them. In particular, farmers want to respond when they perceive failure in their plots. They do not want to waste land or resources in the short term. By contrast, scientists need to see the experiment through and take a several season perspective. They do not exactly welcome failure, but they learn from it. Where there are with and without plots, a poor result is an integral part of the learning process if a technology is successful. Similarly, whereas farmers hoped to gain a share of the project's ample resources, the scientists wished to model poverty as closely as possible.

Such differences in agenda can only be overcome over time and through extensive consultation with the clients of the research. This should include the provision of training for farmers where necessary. This consultation has to be institutionalized so that it is a regular part of the project's activities, as normal as measuring pest damage or yield. The two-plot system has offered solutions to several of the issues faced by the project, and a variation on this for future on-farm research is highly recommended. The unexpectedness of some of the results shows how worthwhile handing over a part of the learning process to farmers can be.

Perhaps the most important lesson here is that any project and its funders must be flexible so that they can respond to what they find in the field. This cannot be known in its entirety until the research is underway. At the end of the day, a project should be assessed not only on technical results, but on the level of co-operation and mutual understanding that has had to be achieved to gain those results.

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DISCUSSION

I. Hoeschle-Zeledon. The two-plot system: did farmers repeat the same trials without your supervision and if yes, did they have the necessary land?

J. L.-M. The farmers did not repeat the trials, they were just given the same inputs and we observed what they were doing, whether or not they adopted some of our technologies.

B. Mwale. It was an opportunity for the research team to evaluate the adoption of the technologies that we were testing with farmers.

Experimental trials within the FSIPM Project and related statistical issues

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ABSTRACT

This paper presents an outline of experimental details concerning on-farm and on-station trials conducted during three crop seasons of the Farming Systems Integrated Pest Management (FSIPM) Project. Statistical and computing issues associated with on-farm trials are discussed and illustrated using examples from FSIPM work. Statistical issues addressed include (i) recognizing the inability to replicate all treatments within each farm, (ii) the need for using concepts associated with the design of surveys together with concepts associated with the design of on-station experiments, (iii) the importance of recognizing multiple levels of variation (e.g. farm level, plot level), taking account of different sources of variation in evaluating pest management strategies, and (iv) the use of non-standard methods of analysis. On the computing side, the critically important issue of ensuring good quality data by having a well-defined system for data management is emphasized. A brief outline is given of the main stages to be considered within the data management process.

INTRODUCTION

A number of experimental trials, both on-station and on-farm, were conducted during the three cropping seasons (1996/97, 1997/98 and 1998/99) of the Farming Systems Integrated Pest Management (FSIPM) Project, in order to investigate a range of potential strategies for improved pest management.

The aim of this paper is to present a brief overview of the design aspects of these trials and to discuss some interesting aspects of statistical methodology that are typical of experiments conducted on farmers' fields. Particular emphasis is given to methodological issues concerning the analysis of on-farm data with reference to FSIPM's experimental trials.

EXPERIMENTS WITHIN FSIPM

Main intercrop trial

The aim of the main intercrop trial, conducted in each of the three cropping seasons, was to investigate pest management strategies under a maize/bean/pigeonpea intercropping system. Experimental details are provided in Appendix 1. An outline is provided in Table 1.

Striga trial

In the 1996/97 season, 10 farmers (five from Chiradzulu uplands and five from Matapwata uplands) were included

Table 1. Experimental details concerning the main intercrop trial

	1996/97	1997/98	1998/99
Maize	Two factors: seed dressing; banking	Two factors: seed dressing; banking	–
Beans	Five factors: mulching; earthing; seed dressing; planting density; variety	One factor: varietal tolerance	One factor: varietal tolerance
Pigeonpea	Two factors: variety; planting position	One factor: varietal tolerance	One factor: varietal tolerance
No. of farmers	64	61	40
No. of plots	122	244	160

in a trial to investigate the effects of different methods of fertilizer application, i.e. no application or dolloped or spread fertilizer, and the use of a trap crop (soyabean) and green manure (*Tephrosia*), for the management of *Striga* in plots planted with maize (MH18), bean (Kalima) and pigeonpea (local). The layout is shown in Appendix 2.

Factor f:
f_0 = no fertilizer
f_1 = (50 kg N/ha spread)
f_2 = (50 kg N/ha dolloped)

Factor t:
t_0 = no *Tephrosia* or soyabean
t_1 = *Tephrosia*
t_2 = soyabean

In the 1997/98 season, the experiment included two treatment factors: use or otherwise of fertilizer; use of a legume treatment factor, i.e. no legume, the use of *Tephrosia* or the use of cowpea. The treatments thus were:

Factor f:
f_0 = no fertilizer
f_1 = fertilizer applied

Factor t:
t_0 = no *Tephrosia* or cowpea
t_1 = *Tephrosia*
t_2 = cowpea

Six farmers participated in the trial. Three of the farmers permitted the use of more than one field (block) in their farm for this researcher designed and managed experiment. The experimental layout and instances where extra replicates (blocks) occurred for some of the farmers are shown in Appendix 2.

The trial was repeated in 1998/99 with the same set of farmers and the same treatments as in 1998/99 except that *Crotalaria* was undersown in the extra control plot.

On-station trials at Thuchila

Two experiments were conducted in the 1996/97 crop season at Thuchila. The first was to compare six maize varieties and the second was to compare six pigeonpea varieties.

Maize trial at Thuchila

The trial involved just one treatment factor, namely maize variety. Six varieties were included to study their tolerance to pest attacks. The varieties were:

1 = MH17
2 = NSCM41
3 = LOCAL
4 = CCC
5 = SYNTHETIC C
6 = MH18

The experiment was planned as a randomized complete block design with four blocks labelled A, B, C, D, but because of the presence of termite mounds in two of the plots, the affected plots were placed elsewhere, i.e. by increasing the number of plots in Block A by 1, and by shifting all plots in Block D away from the termite mound. The resulting design structure is shown in Figure 1a.

(a)

							Block
5	6	2	4	5	3	1	**A**
	2	5	6	1	4	3	**B**
	1	2	3	Termite mound	6	4	**C**
6	5	4	1	3	2	Termite mound	**D**

(b)

							Block
	6	4	1	5	3	1	**A**
	2	5	6	1	4	3	**B**
	5	1	2	3	6	4	**C**
6	5	4	1	3	Termite mound	2	**D**

Figure 1. Design structure of (a) maize and (b) pigeonpea trials at Thuchila.

Pigeonpea trial at Thuchila

The aim of this trial was to compare pigeonpea yields and *Fusarium* wilt disease incidence across six different varieties of pigeonpea, and to investigate how plant deaths due to pest attacks by whitegrubs, termites and other causes, as measured by numbers of dead plants, varied across the pigeonpea varieties. The trial involved just one treatment factor, namely the pigeonpea variety; six varieties were included. The varieties were:

1 = ICP9145
2 = QP38
3 = ICPL86012
4 = ROYES
5 = ICPL87105
6 = LOCAL

The experiment was planned as a randomized complete block design with four blocks labelled A, B, C, D, but because of the presence of a termite mound on one of the plots, the affected plot was placed elsewhere, i.e. by shifting five plots in Block D away from the termite mound. The resulting design structure is shown in Figure 1b.

The presence of the termite mound in this experiment caused no difficulty since the number of plots remained equal in each block. Hence, standard techniques for analysing data from a complete block design apply and raw treatment means were used.

On-station trials at Bvumbwe Research Station

In the 1996/97 season, a trial was conducted to investigate the effect of treating bean seeds with one of six chemical treatments to control the occurrence of bean stem maggot attack on beans. The chemicals were derived from various sources: (i) neem; (ii) *Tephrosia*; (iii) dema root; (iv) carbaryl (Sevin); (v) imidacloprid (Gaucho); and (vi) control. The aim was to investigate whether these treatments would reduce the occurrence of bean stem maggot.

In the 1997/98 season, a second experiment was conducted. The aim of this trial was to evaluate six newly released or experimental bean varieties against natural infestation of bean stem maggot. The experiment was carried out using a randomized complete block design with four replicates. The varieties investigated were:

Mlama 127
G22501
PAD3
Nagaga
Napilira
Kalima
Kaulesi

On-farm trials at Mangunda section of Matapwata EPA

In the 1997/98 season, an on-farm trial to evaluate the performance of seven pigeonpea varieties in terms of their yield potential and resistance to *Fusarium* wilt disease was investigated. Five farmers from the Mangunda section of Matapwata Extension Planning Area (EPA) participated in the trial. The design was planned by the FSIPM team as a randomized complete block design with each of the seven varieties grown on seven plots in each farm. The allocation of varieties to plots in each farm was made at random. The experimental design can thus be regarded as a randomized complete block design with farmers comprising the blocks.

The varieties investigated were:

1 = ICEAP 00020
2 = ICEAP 00040
3 = ICEAP 00053
4 = ICP 9145
5 = QP 38
6 = ROYES
7 = LOCAL

In the 1998/99 season, most of the same farmers participated in a follow-up trial. Twelve plots were used within each farm as parts of two separate experiments. One experiment evaluated four medium duration pigeonpea varieties, i.e. ICP 6927, Chilinga, ICEAP 00073 and ICEAP 00068 grown as an intercrop with maize. This experiment could be regarded as a randomized block design taking the five farms as blocks. The second experiment was set up as a split plot design to compare four long duration pigeonpea varieties, i.e. ICP 9145, ICEAP 00053, ICEAP 00040 and a local, grown as a sole crop or as an intercrop with maize. The type of cropping pattern was applied to the main plots and varieties to the split plots. All plots where maize was grown received fertilizer.

Sweet potato trials

Trials were conducted in Mangunda section of Matapwata EPA and in Chiradzulu to investigate the effects of different timings of crack sealing in reducing damage to sweet potato tubers by the weevil *Cylas puncticollis*. In Mangunda, five treatments were used: farmer practice (FP), FP + 1 early sealing, FP + 1 late sealing, FP + 2 sealings, FP + 3 sealings. Eight plots were used in each of five farms. Hence, the treatments were unequally replicated within each farm, some treatments replicated twice within a farm and some only once.

In Chiradzulu, two separate, but similar experiments were conducted, each involving six farmers. One experiment was conducted in Chiradzulu uplands and one in Chiradzulu *dambo*. Four treatments were studied within each experiment, i.e. FP, FP + 1 sealing, FP + 2 sealings, FP + 3 sealings. Eight plots were used within each farm with each treatment replicated twice within each farm. Both experiments were designed as randomized block experiments with farmers as blocks.

Fertilizer and green manure trial

A small-scale on-farm trial was set up in the 1998/99 season to study the effects of early and late fertilizer timings and the value of two green manures to enhance soil fertility and increase maize production. The trial involved 22 farmers distributed between Kambuwa and Magomero villages. The 22 farm locations were chosen to represent 11 *dambo* sites and 11 upland sites. The factors investigated were:

timing of fertilizer application:

- early – application at crop emergence (researcher practice)
- late – application 4 weeks after crop emergence (farmer practice)

use of green manure

- *Crotalaria* undersown at first weeding
- *Tephrosia* planted alongside the maize
- no green manure grown.

In each farm, either *Crotalaria* or *Tephrosia* were grown in two of the four 'research' plots in each farm. *Crotalaria* was planted in six *dambo* and five upland sites. *Tephrosia* was grown in five *dambo* and six upland sites. One pair of plots in each farm had a late fertilizer application, the remaining pair had an early fertilizer application. One plot of each pair had a green manure grown within a maize/pigeonpea intercrop. The remaining plot of the pair had no legume. Gross plot size was 5.4 x 5.4 m^2. Net plot sizes for maize, pigeonpea, *Tephrosia* and *Crotalaria* were 3.6 x 3.6 m^2, 3.6 x 2.7 m^2, 3.6 x 4.5 m^2 and 3.6 x 5.4 m^2, respectively. All plots received 50 kg/ha N.

OVERVIEW OF STATISTICAL AND COMPUTING ISSUES IN ON-FARM TRIALS

In any research study, there are three main areas where statistical considerations have an important role to play in ensuring that results from data collection activities give reliable and meaningful answers in a form that fulfil study objectives. These are:

- aspects concerning the design of the trial
- effective management of the data
- analysis of the data.

These are briefly discussed in turn below in relation to activities within the FSIPM Project.

Issues concerning study design

One key point to consider at the design stage of on-farm trials, particularly where farmer participation is considerable, is the need to use ideas normally associated with the design of surveys, together with standard concepts associated with the design of on-station experiments. The latter concepts apply in relation to data collected at the plot level, while survey principles generally apply to data collected at the farm level. Thus, in the selection of farmers for inclusion in the study, the target population, i.e. the recommendation domain for which results are intended, must be kept in mind. The sample chosen should be appropriately representative of this domain with respect to key characteristics of the farmers. In the FSIPM Project trials, for example, a stratification of farmers with respect to the type of land they farm (i.e. whether *dambo* or upland) was used. At the data analysis stage, it was clear that this was an important feature concerning variation at the farm level.

Survey elements also enter with respect to plot level information when, for example, farmers are asked to score experimental treatments at plot level.

Other concepts of design include the choice of treatments and units, the number of treatments to use, the number of treatments per farm, procedures for allocating treatments to experimental units, plot size and shape, the exact specification of a control plot, what measurements to use, and matching the degree of replication required with available resources to get statistically meaningful results. These are discussed in the booklet titled *On-farm Trials: Some Biometric Guidelines* (SSC, 1998a).

Issues concerning data management

A well-defined system of data management is crucially important within any research project which involves the collection of a large volume of data. The FSIPM Project was forced into different data management strategies in each of its 3 years – with varying degrees of success, but has nevertheless paid careful attention to data quality throughout its activities over three cropping seasons.

Data collection

Recording data accurately in the field requires considerable effort, prior to field data collection, to ensure, for example, that the recording sheets are appropriate and set up in a form that will allow the data to be later entered directly to a computer. The recording form should be pre-tested in the field and modified if needed. It should include space for comments by the data collection team so that any unusual events or observations can be recorded. Units of measurements must be made clear. Additional variates may be recorded for checking purposes (e.g. total number of dead plants per plot adding to the number of plants dead by different causes).

At the time of data collection, the team should be alert in spotting ambiguities (e.g. pigeonpea plots where large numbers of plants with pods are recorded should also generally have higher pod yield records). The data collection team must be clear about the difference between recording a zero value (e.g. a plot with high disease attack and yielding no pods) and a missing value (e.g. farmer harvesting the crop in advance). The team as well as the farmers must be made aware of the importance of gathering high quality data.

Entering raw data in the computer

This requires: (i) a clear specification of the data collection sheet so that it is in a form suitable for entering the data directly from the recording sheet to the computer; (ii) paying attention to the data structure (e.g. providing links between key variables when the data structure is hierarchical); (iii) identifying suitable software for the data entry process; and (iv) having a workable strategy for data entry and checking.

Organizing the data for analysis

Re-structuring the data into an appropriate form for analysis is often a first step in the data organization process. In the FSIPM Project experimental trials, for example, damage to plants by pests and diseases was recorded throughout the season at several sampling occasions. Data from each occasion were entered on to a single sheet in an Excel file at the data entry stage, but for analysis, data from each of several sheets (corresponding to multiple sampling occasions) had to be collated into a single sheet for analysis.

Often, different versions of the data are created for different analysis purposes. Here it is important to keep a record of all the different data files that are created. If errors in the data are identified, corrections should be made in the 'master copy' of the data, and all back-up files updated.

Archiving the data

The archiving of all information collected during a research study is a valuable resource for further exploration of the data at a subsequent stage and for access by others involved in similar research studies. The archive is not merely a storage place for only the computerized data files. It must also include other information, such as details of the trial design, reports concerning the trial, photographs, etc.

Further details concerning data management issues can be found in the booklet entitled *Data Management Guidelines for Experimental Projects* (SSC, 1998b).

Analysis of the data

Since on-farm trials typically give rise to data that are collected at both farm level and plot level, the analysis can be viewed in three stages:

- analysis of farm level information
- analysis of plot level information

Table 2. Experimental details concerning the main intercrop trial

Experiment 1 in 1996/97	
Number of farmers	64 (one research plot/farm)
Treatment structure	Eight factors at two levels and one factor at three levels
Maize	Seed dressing with one or two doses of carbaryl (Sevin) or no dressing
	Banking at second weeding (Yes/No)
Bean	Seed dressing with carbaryl (Sevin) (Yes/No)
	Earthing (Yes/No)
	Mulching (Yes/No)
	Use of a variety tolerant to bean stem maggot (Kaulesi or Kalima)
	Planting density at high or low levels
Pigeonpea	Use of a wilt-resistant variety, ICP9145 or the local variety
	Planting on ridge side or in rows
Blocking structure	Land type (*dambo*/upland) and EPA
Unit of measurement for experimental treatments	An individual farm
Experiment 2 in 1997/98	
Number of farmers	61 (four research plots/farm)
Treatment structure	Two factors each at two levels, and two factors each at four levels
Maize	Banking (Yes/No)
	Seed dressing with imidacloprid (Gaucho) (Yes/No)
Bean	Use of a variety tolerant to bean stem maggot (Kaulesi, Nagaga, Napilira or Kalima)
Pigeonpea	Use of a wilt-resistant variety (ICEAP 00053, ICEAP 00040, ICP 9145 or the local variety)
Blocking structure	Land type/EPA, and farms within these two strata
Unit of measurement for experimental treatments	Plots within farms
Experiment 3 in 1998/99	
Number of farmers	40 (four research plots/farm)
Treatment structure	Two factors, each at four levels
Bean	Use of a variety tolerant to bean stem maggot (Kaulesi, Nagaga, Napilira or Kalima)
Pigeonpea	Use of a wilt-resistant variety (ICEAP 00053, ICEAP 00040, ICP 9145 or the local variety)
Blocking structure	Land type/EPA, and farms within these two strata
Unit of measurement for experimental treatments	Plots within farms

- analyses which combine farm-level and plot-level information.

If trials are conducted at a number of different sites (e.g. differing agro-ecological regions), or over a number of different years, analyses which combine results across sites and years should also be considered.

Within the FSIPM Project activities, most of the socio-economic studies took place at the farm level, while agronomic and pest management work took place at the plot level. The latter involved experimental trials conducted on farmers' fields which were largely researcher-designed but managed by the farmers.

Since the first author's work as a biometrician was mostly in relation to the experimental analysis work, the main focus in the remainder of this paper will be on methodological aspects relating to statistical treatment of the data during data analysis.

METHODOLOGICAL ASPECTS IN DATA ANALYSIS

Some important aspects of statistical methodology used in analysing data from the FSIPM Project's experimental trials are presented in this section. A number of trials were conducted in each of the three cropping seasons, but only one trial will be used here for purposes of illustration.

Recognizing the data structure

The illustrative example is the main intercrop trial conducted each year under a maize/bean/pigeonpea intercropping system. Basic details concerning this trial are shown in Table 2.

One of the difficulties associated with analysing data from on-farm trials can be seen from this example. Information concerning the trial resides at different levels of a hierarchy. Thus Table 2 shows information associated with the experiment in each of 3 years. This forms the highest level of the hierarchy. At the next level of the hierarchy, we have information collected within a year at a farmer level, e.g. land type (or zone, i.e. whether *dambo* or upland), socio-economic variables concerning the farmer, and soil nutrient measurements. At the lowest level of the hierarchy, we have plot level information.

The hierarchical structure implies that due consideration should be given at the study design stage to the types of measurements to be collected at each level and how they should be linked in relation to the objectives of the experiment. For example, variation in crop yields (i.e. plot level data) across different pest management strategies (again applied at plot level) may need to be explored within different groups of farmers, the farmer groups being identified through a stratification of farmers according to their socio-economic characteristics, i.e. according to farm level information.

In analysing information such as crop yields (i.e. plot level data), it is also important to consider whether this analysis should take place across plots within each farm, across all farms within each year, or across all years. In the example above, the latter procedure is inappropriate because the treatment structure varies from year to year. However, within any year, an analysis that combines farm level stratification variables with plot level information is very relevant. In particular, it allows interactions between farm level variables and plot level variables to be explored. Unlike on-station trials where block by treatment interactions can usually be regarded as non-existent, in on-farm trials, the farm by treatment interaction is of particular importance. If this interaction exists, then it is important to determine reasons for this interaction, for example, whether the interaction can be explained in terms of the variation in socio-economic variables.

Table 3. Mean usable maize grain yield with or without seed dressing

Land type	With dressing	Without dressing	Difference in means
Dambo	1312	1193	119
Upland	2721	2216	505

Table 3 illustrates the interaction between the application of seed dressing with Gaucho (i.e. a plot level treatment) and type of farmland (i.e. a farm level stratification variable), when studying the effect of seed dressing on usable maize grain yields (kg/ha). It is clear that seed dressing has a beneficial effect, but the increase in maize yields under seed dressing is much greater (about 500 kg/ha) in the uplands than in the *dambo* areas where the increase is only about 100 kg/ha.

Study of variation due to different causes

The main statistical technique used for analysing yield data was the analysis of variance (ANOVA). This is a standard method for separating the overall variation in the data into components so that each component reflects variation due to a different source. For example, the 1997/98 main intercrop trial involved 61 farmers with four plots on each farm, two of which were seed dressed with Gaucho while the remaining two plots were left untreated. The ANOVA structure here may take, for example, the following form:

Source of variation	Degrees of freedom
EPA	1
Land type (*dambo*/upland)	1
Between farm variation	58
Seed dressing	1
Land type × seed dressing interaction	1
EPA × seed dressing interaction	1
Within farm variation	180
Total variation	243

Additional sources of variation may enter this analysis at either the farm level or the plot level. Soil measurements, for example, may be relevant at either level, but will depend on whether soil measurements were taken on each plot in a farm or a composite soil sample was taken at the farm level.

With two levels of variation involved in this analysis, summaries such as the coefficient of variation (CV) have little relevance unless the level of variation is specified. Even then, the value of a CV as a summary measure for reporting purposes is limited. The more important issue is to recognize that large farm to farm variation is likely to be the norm in on-farm trials, and that this variation needs to be explored further to ascertain reasons for the high farm to farm variation. Further investigations of this nature, taking account of information available at the farm level, are important since they may well serve in identifying recommendation domains that are appropriate for IPM interventions being investigated via on-farm experimental trials.

Non-standard methods of analysis

It is almost inevitable that on-farm trials will lead to data that have to be analysed using non-standard statistical procedures (Mead, 1988; Martin and Sherington, 1997). There are several reasons for this.

(i) Firstly, it is quite unusual for even one replicate of all treatments to be tested within a single farm. This is often because each farmer is unable to allocate more than three or four plots for research trials. If the number of treatments to be investigated is larger than the number of plots available within a farm, then it will not be possible to include every treatment within every farm. In the 1997/98 season, for instance, it was relevant to investigate whether or not maize seed dressing had an effect on bean yields, as well as to investigate how bean yields varied across four different bean varieties. This resulted in eight treatment combinations (i.e. seed dressed or not with each of four varieties). However, only four of these could be applied to the four plots available on any farm. This leads to an analysis which is non-standard but which can be handled with good statistical software.

(ii) It may also happen that some farmers can provide only a few plots while others are able to provide more plots. For example, in the 1997/98 trial to investigate the use of trap crops and application of fertilizer for management of the parasitic weed *Striga asiatica*, six farmers were involved. Three were able to provide four main plots (each subdivided into two) for allocation of the trap crop, two farmers provided eight main plots each, while the remaining farmer had enough land to allocate 12 main plots for the trial. When a relatively large number of plots within a single farm are included, attention is also needed at the design stage of the experiment to possible sources of variability (fertility gradients, sloping land, etc.) within that farm. Usually some kind of within farm blocking would be needed.

(iii) A further complication that is generally almost always present in on-farm trials, is the occurrence of missing data. This happens, for example, when the farmer harvests all the plots rather than keeping the harvests from each plot separate, or when some unusual event happens (e.g. field mice eating maize cobs).

(iv) When missing data occur, or when the design itself leads to fewer than the full set of treatment combinations being tested on any given farm, summarizing the data in the form of simple averages to represent the effect of each treatment is no longer appropriate. Inevitably there is considerable farm-to-farm variation. Hence, the analysis must allow for such variation before investigating treatment effects. In particular, results concerning the mean effect of each treatment must be reported in terms of *adjusted treatment means*, i.e. means that have been adjusted for (or freed from) other extraneous sources of variation. Failure to do so can lead to misleading results since they will be confounded with farm-to-farm variability as well as other sources of variability that exist between or within farms. Reporting results in terms of adjusted means also becomes necessary when additional quantitative measurements (such as soil nutrient measurements or amounts of fertilizer applied) are made on the experimental units and included in the analysis as possible sources of variation.

(v) Damage assessments to plants by various pests and diseases generally lead to data sets which are non-normally distributed. Thus data arising in the form of counts (e.g. number of whitegrubs in soil samples taken per plot, number of emerged *Striga* plants) follow a Poisson distribution, while data in the form of proportions or percentages (proportion of germinating plants killed by whitegrubs, proportion of pigeonpea seeds damaged by pod borers) follow a binomial distribution. Such data do not conform to assumptions associated with the ANOVA procedure, and so, more advanced analysis procedures, involving the fitting of generalized linear models, have to be adopted in analysing these types of data (Collett, 1991; Dobson, 1990). Such modern methods of analysis are more appropriate and lead to more meaningful results than traditional analysis methods which were often based on data transformations such as the arc sine or square root transformations.

(vi) It is also typical in pest management trials for data on pest damage and disease incidence to be collected throughout the season at a number of sampling occasions. Such data are referred to as repeated measurements data. Typically, these data require special methods of analysis to take account of correlations among observations made on the same experimental units. This is an added complication in on-farm trials, but was handled within the FSIPM Project by adopting a simple approach whereby the multivariate nature of the data was reduced to a univariate case by using a single statistic to summarize the information across the entire season. The summary was often in terms of totals, e.g. the total number of plants damaged by termites through the season.

DISCUSSION

This paper emphasizes the need to think carefully about many statistical and computing issues concerning the design and analysis of on-farm experimental trials. Although statistical concepts associated with the design of on-station experiments and analysis of data from such trials are still relevant and important, there are several additional issues that must be recognized and considered when dealing with on-farm trials. Of particular relevance is the need to collect additional information concerning the farmers associated with the trial so that in the event of finding a farmer by treatment interaction, reasons for this interaction can be explored and recommendations regarding treatments made for different groups of farmers. It is important to note that such an investigation requires a large number of participating farmers of the order required when conducting surveys of farming populations.

Multiple levels of variation must be recognized and analysis procedures undertaken to take account of different sources of variation at each level of a hierarchically structured set of data. There is also the need to report experimental results in terms of adjusted means when treatments are unequally replicated, when missing data occur and when the analysis procedures involve a mixture of classification variables and quantitatively measured covariates (e.g. treatment factors and soil nutrient measurements). Where possible it is desirable to explain reasons for farm-to-farm variability and use this information to identify suitable recommendation domains.

It is also critically important to keep a clear view of the objectives of the experimental trials and the population to which the results may generally apply. Clarifying the objectives in detail at the start of project activities can help to identify specific pieces of information that need to be collected and analysed. Each data collection activity must be carefully considered so that the resulting information contributes meaningfully towards fulfilling a stated project objective. The selection of farmers for inclusion in the trial must be decided keeping in mind the target population to which project results are anticipated to apply.

Finally, the importance of a clear strategy for data management cannot be over-emphasized. No amount of sophistication with respect to the design of experimental studies and subsequent statistical analysis can overcome the inevitability that research results will be meaningless if they are based on poor quality data. Despite various difficulties faced by the FSIPM Project concerning data management issues, it is possible to claim that the project has made considerable efforts to ensure their experimental data are of the highest possible quality.

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DISCUSSION

A. Sutherland. Given the nature of the project, to test existing new technologies with a farming systems perspective, why was an 'in-trial' approach useful? This is quite different from most projects using a farming systems/adaptive research approach in the region. Would it not have been easier to have a number of discrete trials focusing on key issues, with careful on-farm monitoring alongside?

S. A. Several reasons. (a) A major aim was to look at pest management strategies for maize, bean and pigeonpea grown as an intercrop. Particularly in the initial year, little was known about the way in which a pest management strategy for one crop would affect a pest management strategy for another. Discrete trials would not have identified interactions between the strategies. (b) Many trials would have had resource implications as well as difficulties of building rapport with a larger group of farmers. (c) Further trials were conducted for some strategies, e.g. for *Striga* control, use of green manures for improving soil fertility, crack sealing for control of sweet potato weevil, comparing a range of pigeonpea varieties.

A. M. Chirembo. Why did the FSIMP Project work with four varieties of pigeonpea, for instance, as if it was a breeding study? Why not work with only one or two varieties?

S. A. Firstly it must be pointed out that in 1996/97, when many pest management strategies were explored, only two varieties were included, i.e. a local variety and a wilt resistant variety for pigeonpea and a local variety (Kalima) and Kaulesi for beans. Secondly, breeding studies use a lot more than four varieties. Thirdly, ICRISAT had developed new varieties which have been found to be wilt tolerant in other regions. So exploring the potential of these varieties in the FSIPM Project trials, in addition to the two included in 1996/97 seemed very relevant. For bean, additional varieties (Nagaga and Napilira) included in 1997/98 and 1998/99 were those that had been developed by the CIAT bean programme and found to be pest and disease resistant.

D. Coyne. Is it possible to analyse the individual components of possible variability to reduce the overall variability, or at least identify the sources of greatest variability?

S. A. The data analysis does take account of all known sources of variability and compares IPM strategies after having allowed for such sources of variability. Much of the farm-to-farm variability, for example, was due to EPA and land type differences. Comparisons between IPM strategies within the FSIPM Project were free from such effects, but where they differed (e.g. across land types) results were provided for each stratum.

J. Mapemba. Was there any attempt to categorize the households participating in trials into poor, rich or poorest?

S. A. The project's economist had developed a categorization of households into five clusters, i.e. burley growers, *dimba* households, stable male-headed and stable-female headed households and vulnerable households. This stratification was incorporated into the analysis but we found that it did not account for additional variability over and above the variability that was due to EPA or *dambo*/upland differences.

APPENDIX 1
Experimental details concerning the main intercrop trial

IN THE 1996/97, 1997/98 AND 1998/99 CROP SEASONS

Background

In each of the three crop seasons, the trials were conducted in four villages, i.e. Chiwinja and Lidala in the Chiradzulu EPA, and villages Magomero and Kambuwa in the Matapwata EPA. The project was aimed at resource-poor subsistence farmers within the maize/pigeonpea/bean intercropping systems. The distribution of farmers across type of farmland, EPAs and villages is shown in Table 4.

Experimental design and treatments used in the 1996/97 trial

In the 1996/97 season, several pest management strategies (hereafter referred to as 'treatment factors') were explored in the first year of the FSIPM Project trials. Different strategies were used for maize, bean and pigeonpea as described below.

The nine treatment factors included in the 1996/97 main intercrop trial are shown below.

g/w, seed dressing maize with carbaryl (Sevin) (85% WP formulation) with g being two doses and w being one dose
absence of letter g or w represents control, i.e. no seed dressing
t, indicates maize termite treatment (different in two locations)
absence of letter t represents control, i.e. weed and bank at second weeding
i, indicates use of wilt-resistant pigeonpea variety ICP 9145
absence of letter i represents control, i.e. local pigeonpea variety
r, indicates pigeonpea planted on ridge side
absence of letter r represents control, i.e. planting in rows
s, indicates bean seed dressing with carbaryl (Sevin) for beanfly
absence of letter s represents control, i.e. no bean seed dressing
b, indicates earthing up bean plants
absence of letter b represents control, i.e. no earthing up
m, indicates mulching of beans
absence of letter m represents control, i.e. no mulching
v, indicates tolerant bean variety (Kaulesi or Kalima)
absence of letter v represents control, i.e. Chimbamba
p, indicates planting density is high
absence of letter p represents control, i.e. planting density is low.

Table 4. Distribution of farmers across villages and land types in three crop seasons

Land type (zone)	Chiradzulu		Matapwata		
	Chiwinja	Lidala	Kambuwa	Magomero	Total
1996/97					
Dambo	8	8	10	6	32
Upland	8	8	6	10	32
Total	16	16	16	16	64
1997/98					
Dambo	11	6	8	5	30
Upland	5	12	7	7	31
Total	16	18	15	12	61
1998/99					
Dambo	8	6	4	5	23
Upland	2	8	3	4	17
Total	10	14	7	9	40

Following discussions with FSIPM Project staff, there appeared to be little knowledge of likely interactions between the above factors. Hence it seemed appropriate to design the trials in such a way so that interactions between factors within each of three separate sets of factors (strategies) could be measured. The three sets were:

(i) factors concerned with whitegrub and termite control in maize, i.e. g/w and t

(ii) factors concerned with control of wilting in pigeonpea, i.e. i and r

(iii) factors concerned with control of beanfly in beans, i.e. s, b, m, v and p.

For various reasons, not all trials or all factors were to be included in each EPA and each of *dambo* and upland areas.

The main intercrop trial involved nine factors, but since factor g was to be tested only in *dambo* areas and t only in upland areas, the trial could be regarded as involving just 8 factors. The number of levels of all but factor g was 2 and hence a slightly modified fractional replicate of a 2^8 factorial was thought a reasonable design to use. (The slight modification needed was to take account of factor g being at 3 levels.)

Since $2^8 = 256$ represented the total number of treatment combinations, a quarter of this was considered, i.e. use of 64 plots. Project staff felt that with 1 plot/farm, carrying out fieldwork with 64 farms was practically feasible. It was agreed that an additional plot in each farm with the farmers' own practice would be useful for purposes of local comparison. The design finally proposed appears in Table 5.

Experimental design and treatments used in the 1997/98 trial

FSIPM Project trials in the 1997/98 season were a follow-up to trials conducted in the 1996/97 season in two villages in each of Chiradzulu and Matapwata EPAs. During 1996/97, the design was set up as an incomplete factorial design with a fractional replicate, one plot in each of the 64 farms being used as the experimental units. The design was planned to ensure that all relevant 2-factor interactions could be estimated from the data. One complication with this design was that each farmer saw only one treatment combination. They were, therefore, unable to observe the effect of the different treatments. Hence in the 1997/98 season, the total number of intervention treatments was reduced to fewer factors: 2 for maize, 1 for pigeonpea and 1 for bean. The trial was designed to ensure that most of the proposed treatment combinations were visible to each farmer on one or more of the four experimental plots on his/her farm.

The design was again an incomplete block design with a factorial treatment structure with 4 units/ farm forming a block. Allocation of treatments to the incomplete blocks was made so that all important 2-factor interactions could be estimated. The design layout (unrandomized) for farms in each village and by zone (*dambo*/upland) appears below in Table 6.

Four treatment factors were included in the trial. For maize, 1 factor, i.e. seed dressing with Gaucho, was used for the management of whitegrubs, and 1 factor, i.e. *mbwera* or no *mbwera* in Matapwata, and weeding with banking or weeding without banking (in Chiradzulu North) was used for the control of termites.

On bean and pigeonpea, only varietal tolerance was investigated. For bean, four varieties were used:

- control, local check: Kaulesi
- tolerant variety: Nagaga
- tolerant variety: Napilira
- tolerant variety: Kalima.

For pigeonpeas, four varieties were used:

- control, local pigeonpea
- ICEAP 00053 variety
- ICEAP 00040 variety
- ICP 9145 variety.

Table 5. Final design for the main intercrop trial in the 1996/97 season

Block 1 *Dambo* in Matapwata							
irg	sbirg	smig	bmig	spirg	bpirg	mpigw	sbmpigw
svrw	bvrw	mvw	sbmvw	pvr	sbpvr	smpv	bmpv
Block 2 Upland in Matapwata							
sirt	birt	mit	sbmit	pirt	sbpirt	smpit	bmpit
vt	sbvt	smvrt	bmvrt	spv	bpv	mpvr	sbmpvr
Block 3 Upland in Chiradzulu							
s	b	mr	sbmr	p	sbp	smpr	bmpr
vi	sbvi	smvir	bmvir	spvit	bpvit	mpvirt	sbmpvirt
Block 4 *Dambo* in Chiradzulu (no beans here, so no bean treatments)							
g	ig	rw	irw	g	ig	rg	irg
w	iw	rw	irw	1	i	r	ir

t, Different termite treatment in the two locations.

Table 6. Allocation of treatments in the main trial for maize/pigeopea/bean intercrop

Farmer	Plot 1	Plot 2	Plot 3	Plot 4
Block 1 *Dambo* in Chiradzulu North, Chiwinja (11 farms)				
1	$i_0 v_3 g_1$	$i_1 v_2 g_0$	$i_2 v_1 g_1$	$i_3 v_0 g_0$
2	$i_0 v_0 g_0$	$i_1 v_3 g_1$	$i_2 v_2 g_0$	$i_3 v_1 g_1$
3	$i_0 v_1 g_1$	$i_1 v_0 g_0$	$i_2 v_3 g_1$	$i_3 v_2 g_0$
4	$i_0 v_2 g_1$	$i_1 v_1 g_0$	$i_2 v_0 g_0$	$i_3 v_3 g_0$
5	$i_0 v_3 g_0$	$i_1 v_2 g_0$	$i_2 v_1 g_0$	$i_3 v_0 g_1$
6	$i_0 v_0 g_1$	$i_1 v_3 g_1$	$i_2 v_2 g_1$	$i_3 v_1 g_0$
7	$i_0 v_1 g_0$	$i_1 v_0 g_1$	$i_2 v_3 g_0$	$i_3 v_2 g_1$
8	$i_0 v_2 g_1$	$i_1 v_1 g_1$	$i_2 v_0 g_1$	$i_3 v_3 g_0$
9	$i_0 t_0 v_3 g_0$	$i_1 t_1 v_2 g_1$	$i_2 t_0 v_1 g_0$	$i_3 t_1 v_0 g_1$
10	$i_0 t_0 v_0 g_0$	$i_1 t_1 v_3 g_1$	$i_2 t_0 v_2 g_0$	$i_3 t_1 v_1 g_1$
11	$i_0 t_1 v_1 g_0$	$i_1 t_0 v_0 g_1$	$i_2 t_1 v_3 g_0$	$i_3 t_0 v_2 g_1$
Block 2 *Dambo* in Chiradzulu North, Lidala (6 farms)				
1	$i_0 v_3 g_1$	$i_1 v_2 g_0$	$i_2 v_1 g_1$	$i_3 v_0 g_0$
2	$i_0 v_0 g_0$	$i_1 v_3 g_1$	$i_2 v_2 g_0$	$i_3 v_1 g_1$
3	$i_0 v_1 g_1$	$i_1 v_0 g_0$	$i_2 v_3 g_1$	$i_3 v_2 g_0$
4	$i_0 v_2 g_1$	$i_1 v_1 g_0$	$i_2 v_0 g_0$	$i_3 v_3 g_1$
5	$i_0 v_3 g_0$	$i_1 v_2 g_1$	$i_2 v_1 g_1$	$i_3 v_0 g_1$
6	$i_0 v_0 g_1$	$i_1 v_3 g_0$	$i_2 v_2 g_1$	$i_3 v_1 g_0$
Block 3 Upland in Chiradzulu North, Chiwinja (5 farms)				
1	$i_0 t_1 v_0 g_1$	$i_1 t_0 v_3 g_0$	$i_2 t_1 v_2 g_1$	$i_3 t_0 v_1 g_0$
2	$i_0 t_0 v_1 g_1$	$i_1 t_1 v_0 g_0$	$i_2 t_0 v_3 g_1$	$i_3 t_1 v_2 g_0$
3	$i_0 t_1 v_2 g_0$	$i_1 t_0 v_1 g_1$	$i_2 t_1 v_0 g_0$	$i_3 t_0 v_3 g_1$
4	$i_0 t_1 v_3 g_1$	$i_1 t_0 v_2 g_0$	$i_2 t_1 v_1 g_1$	$i_3 t_0 v_0 g_0$
5	$i_0 t_0 v_2 g_1$	$i_1 t_1 v_1 g_0$	$i_2 t_0 v_0 g_1$	$i_3 t_1 v_3 g_0$
Block 4 Upland in Chiradzulu North, Lidala (12 farms)				
1	$i_0 t_1 v_3 g_0$	$i_1 t_0 v_2 g_1$	$i_2 t_1 v_1 g_0$	$i_3 t_0 v_0 g_1$
2	$i_0 t_0 v_0 g_1$	$i_1 t_1 v_3 g_0$	$i_2 t_0 v_2 g_1$	$i_3 t_1 v_1 g_0$
3	$i_0 t_1 v_1 g_1$	$i_1 t_0 v_0 g_0$	$i_2 t_1 v_1 g_1$	$i_3 t_0 v_2 g_0$
4	$i_0 t_0 v_2 g_0$	$i_1 t_1 v_1 g_1$	$i_2 t_0 v_0 g_0$	$i_3 t_1 v_3 g_1$
5	$i_0 t_0 v_1 g_1$	$i_1 t_1 v_2 g_0$	$i_2 t_0 v_1 g_1$	$i_3 t_1 v_0 g_0$
6	$i_0 t_1 v_0 g_0$	$i_1 t_0 v_3 g_1$	$i_2 t_1 v_2 g_0$	$i_3 t_0 v_1 g_1$
7	$i_0 t_0 v_1 g_0$	$i_1 t_1 v_0 g_1$	$i_2 t_0 v_3 g_0$	$i_3 t_1 v_2 g_1$
8	$i_0 t_1 v_2 g_1$	$i_1 t_0 v_1 g_0$	$i_2 t_1 v_0 g_1$	$i_3 t_0 v_3 g_0$
9	$i_0 t_0 v_3 g_0$	$i_1 t_1 v_2 g_1$	$i_2 t_0 v_1 g_0$	$i_3 t_1 v_0 g_1$
10	$i_0 t_1 v_0 g_1$	$i_1 t_0 v_3 g_0$	$i_2 t_1 v_2 g_1$	$i_3 t_0 v_1 g_0$
11	$i_0 t_0 v_1 g_1$	$i_1 t_1 v_0 g_0$	$i_2 t_0 v_3 g_1$	$i_3 t_1 v_2 g_0$
12	$i_0 t_1 v_2 g_0$	$i_1 t_0 v_1 g_1$	$i_2 t_1 v_0 g_0$	$i_3 t_0 v_3 g_1$
Block 5 *Dambo* in Matapwata, Magomero (5 farms)				
1	$i_0 g_1 v_3$	$i_1 g_0 v_2$	$i_2 g_1 v_1$	$i_3 g_0 v_0$
2	$i_0 g_0 v_0$	$i_1 g_1 v_3$	$i_2 g_0 v_2$	$i_3 g_1 v_1$
3	$i_0 g_1 v_1$	$i_1 g_0 v_0$	$i_2 g_1 v_3$	$i_3 g_0 v_2$
4	$i_0 g_0 v_2$	$i_1 g_1 v_1$	$i_2 g_0 v_0$	$i_3 g_1 v_3$
5	$i_0 g_0 v_3$	$i_1 g_1 v_2$	$i_2 g_0 v_1$	$i_3 g_1 v_0$
Block 6 *Dambo* in Matapwata, Kambuwa (8 farms)				
1	$i_0 g_1 v_0$	$i_1 g_0 v_3$	$i_2 g_1 v_2$	$i_3 g_0 v_1$
2	$i_0 g_0 v_1$	$i_1 g_1 v_0$	$i_2 g_0 v_3$	$i_3 g_1 v_2$
3	$i_0 g_1 v_2$	$i_1 g_0 v_1$	$i_2 g_1 v_0$	$i_3 g_0 v_3$
4	$i_0 g_0 v_3$	$i_1 g_1 v_2$	$i_2 g_0 v_1$	$i_3 g_1 v_0$
5	$i_0 g_0 v_0$	$i_1 g_1 v_3$	$i_2 g_0 v_2$	$i_3 g_1 v_1$
6	$i_0 g_1 v_1$	$i_1 g_0 v_0$	$i_2 g_1 v_3$	$i_3 g_0 v_2$
7	$i_0 g_0 v_2$	$i_1 g_1 v_1$	$i_2 g_0 v_0$	$i_3 g_1 v_3$
8	$i_0 g_1 v_3$	$i_1 g_0 v_2$	$i_2 g_1 v_1$	$i_3 g_0 v_0$

Continued

Table 6 continued

Farmer	Plot 1	Plot 2	Plot 3	Plot 4
Block 7 Upland in Matapwata, Magomero (7 farms)				
1	$i_0 t_2 v_3 g_0$	$i_1 t_0 v_2 g_1$	$i_2 t_2 v_1 g_0$	$i_1 t_0 v_0 g_1$
2	$i_0 t_0 v_0 g_1$	$i_1 t_2 v_3 g_0$	$i_2 t_0 v_2 g_1$	$i_3 t_2 v_1 g_0$
3	$i_0 t_2 v_1 g_1$	$i_1 t_0 v_0 g_0$	$i_2 t_2 v_3 g_1$	$i_1 t_0 v_2 g_0$
4	$i_0 t_0 v_2 g_0$	$i_1 t_2 v_1 g_1$	$i_2 t_0 v_0 g_0$	$i_3 t_2 v_3 g_1$
5	$i_0 t_0 v_3 g_1$	$i_1 t_2 v_2 g_0$	$i_2 t_0 v_1 g_1$	$i_3 t_2 v_0 g_0$
6	$i_0 t_2 v_0 g_0$	$i_1 t_0 v_3 g_1$	$i_2 t_2 v_2 g_0$	$i_3 t_0 v_1 g_1$
7	$i_0 t_0 v_1 g_0$	$i_1 t_2 v_0 g_1$	$i_2 t_0 v_3 g_0$	$i_3 t_2 v_2 g_1$
Block 8 Upland in Matapwata, Kambuwa (7 farms)				
1	$i_0 t_2 v_2 g_1$	$i_1 t_0 v_1 g_0$	$i_2 t_2 v_0 g_1$	$i_1 t_0 v_3 g_0$
2	$i_0 t_0 v_3 g_0$	$i_1 t_2 v_2 g_1$	$i_2 t_0 v_1 g_0$	$i_3 t_2 v_0 g_1$
3	$i_0 t_2 v_0 g_1$	$i_1 t_0 v_3 g_0$	$i_2 t_2 v_2 g_1$	$i_3 t_0 v_1 g_0$
4	$i_0 t_0 v_1 g_1$	$i_1 t_2 v_0 g_0$	$i_2 t_0 v_1 g_1$	$i_3 t_2 v_2 g_0$
5	$i_0 t_2 v_2 g_0$	$i_1 t_0 v_1 g_1$	$i_2 t_2 v_0 g_0$	$i_1 t_0 v_1 g_1$
6	$i_0 t_2 v_3 g_1$	$i_1 t_0 v_2 g_0$	$i_2 t_2 v_1 g_1$	$i_3 t_0 v_0 g_0$
7	$i_0 t_0 v_0 g_0$	$i_1 t_2 v_3 g_1$	$i_2 t_0 v_2 g_0$	$i_3 t_2 v_1 g_1$

g	seed dressing maize
g_1	seed dressing maize with imidacloprid (Gaucho, 70 WS formulation)
g_0	control – no seed dressing
t	maize termite treatment (upland only, different in two locations)
t_2	*mbwera* tillage in Matapwata (+ weeding without banking)
t_1	weeding without banking in Chiradzulu North
t_0	control – no *mbwera* in Matapwata (+ weed and bank), weed and bank at second weeding in Chiradzulu North
i	Wilt-resistant pigeonpea
i_3	ICP 9145 variety
i_2	ICEAP 00040 variety
i_1	ICEAP 00053 variety
i_0	control – local pigeonpea
v	tolerant bean variety
v_3	tolerant variety: Kalima
v_2	tolerant variety: Napilira
v_1	tolerant variety: Nagaga
v_0	control, local check, Kaulesi

Experimental design and treatments used in the 1998/99 trial

Only a minority of farmers experienced termite and whitegrub attack in the 1997/98 season. Therefore, fieldwork was restricted to 12 farmers for investigating pest management strategies for termites and another 9 farmers for investigating pest management strategies for whitegrub attack. In the termite management trial, four plots were again used within each farm, each allocated one of the treatment combinations coming from the use or otherwise of banking and seed priming. In the whitegrub management trial, the four plots used in the previous season were each split in half to give eight plots, each 5.4 × 5.4 m². The treatments applied formed a 2 × 2 × 2 factorial structure for the following three treatment factors, i.e. use of Gaucho as a seed dressing in the 1997/98 season or not; use of Gaucho as

Table 7. Treatment allocation in the 1996/97 *Striga* trial

EPA	Farmer	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Chiradzulu	1	f_0t_0	f_0t_1	f_1t_2	f_2t_2	**f_0t_0**
Chiradzulu	2	**f_0t_0**	f_1t_0	f_0t_1	f_2t_2	f_2t_0
Chiradzulu	3	f_0t_1	f_2t_0	f_1t_2	f_1t_1	**f_0t_0**
Chiradzulu	4	f_1t_1	f_0t_2	f_2t_0	f_0t_1	**f_0t_0**
Chiradzulu	5	f_1t_1	**f_0t_0**	f_0t_2	f_2t_0	f_2t_1
Matapwata	6	f_2t_2	**f_0t_0**	f_1t_0	f_0t_0	f_2t_1
Matapwata	7	**f_0t_0**	f_2t_1	f_0t_2	f_1t_0	f_1t_2
Matapwata	8	f_2t_1	f_1t_2	**f_0t_0**	f_2t_2	f_0t_0
Matapwata	9	f_0t_2	f_1t_0	f_1t_1	**f_0t_0**	f_2t_2
Matapwata	10	f_1t_2	f_0t_0	f_1t_1	f_2t_1	**f_0t_0**

seed dressing in 1998/99 or not, and the incorporation or not *Tephrosia* in the plot.

The remaining 40 farmers participated in a trial within a maize/bean/pigeonpea intercropping system to investigate varietal tolerance for bean and pigeonpea. The trial, with 4 plots/farm, was similar to that used in the 1998/99 season but did not involve seed dressing or banking as treatment factors.

APPENDIX 2
Experimental designs for the *Striga* trials

1996/97 SEASON

In the 1996/97 season, 10 farmers were included in a trial to investigate the effects of different methods of fertilizer application, i.e. no application or dolloped or spread fertilizer, and the use of a trap crop (soyabean) and green manure (*Tephrosia*), for the management of *Striga* in plots planted with maize (MH18), bean (Kalima) and pigeonpea (local) (Table 7).

Factor f:
f_0 = no fertilizer
f_1 = 50 kg N/ha spread
f_2 50 kg N/ha dolloped

Factor t:
t_0 = no *Tephrosia* or soyabean
t_1 = *Tephrosia*
t_2 = soyabean

Each plot was of a standard size, 5.4 x 5.4 m, 5 plots/farm. Four of these were labelled as 'research' plots since they included treatment combinations to be evaluated during the trial. The remaining plot was referred to as the 'farmers' plot' since the farmer was allowed to farm this plot according to his/her own practice.

The cropping pattern was maize (MH18), 3 seeds/station, plus pigeonpea (local), 3 seeds/station, both at 90 cm spacing, with one station of bean (Kalima), 2 seeds/station between each pair of adjoining stations, intercropped on ridge. Since there were only 40 plots in the trial for the application of the nine treatment combinations (3 fertilizer treatments by 3 legume treatments), the design was an incomplete block design with the 3 x 3 factorial treatment structure applied as evenly as possible across the 10 farms.

1997/98 SEASON

In the 1997/98 season, the experiment included two treatment factors, namely the use or otherwise of fertilizer; and the use of a legume treatment factor, i.e. no legume, the use of *Tephrosia* or the use of cowpea. The treatments were:

Factor f:
f_0 = no fertilizer
f_1 = fertilizer applied

Table 8. Treatment allocation (before randomization) in the 1997/98 *Striga* trial

Farmer	Block No.	Plot 1		Plot 2		Plot 3		Plot 4	
1	1	f_0t_1	f_1t_1	f_1t_0	f_0t_0	f_0t_2	f_1t_2	f_0t_0	f_1t_0
2	2	f_1t_2	f_0t_2	f_0t_0	f_1t_0	f_0t_1	f_1t_1	f_0t_0	f_1t_0
3 (1st rep)	3	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_0t_1	f_1t_1	f_0t_0	f_1t_0
3 (2nd rep)	4	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0
4	5	f_1t_0	f_0t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1	f_1t_0	f_0t_0
5 (1st rep)	6	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0
5 (2nd rep)	7	f_0t_2	f_1t_2	f_0t_0	f_1t_0	f_1t_1	f_0t_1	f_0t_0	f_1t_0
6 (1st rep)	8	f_0t_0	f_1t_0	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1
6 (2nd rep)	9	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1	f_0t_0	f_1t_0
6 (3rd rep)	10	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0

Factor t:
t_0 = no *Tephrosia* or cowpea
t_1 = *Tephrosia*
t_2 = cowpea

To give farmers the opportunity to compare legume treatments, and at the same time observe fertilizer effects, the experiment was laid down, within each 'block' of area in a farm, as a split-unit design with four main plots (10.8 × 5.4 m), each divided into two to give a total of eight sub-plots (split-plots). Among the four main plots, one had *Tephrosia*, one had cowpea and two plots were left as controls with no legume. Of the sub-plot pair within each main plot, one was left unfertilized and the other was fertilized with CAN at 50 kg N/ha. This arrangement left two of the eight sub-plots within each block with neither a fertilizer application, nor a legume treatment, thus increasing the chances of observing good *Striga* emergence in the absence of any inhibiting treatments. In addition, each farmer had the same combination of treatments and could, therefore, compare his/her own field(s) with those of other farmers.

Six farmers participated in the trial. Three of the farmers permitted the use of more than one field (block) in their farm for this researcher designed and managed experiment. The experimental layout and instances where extra replicates (blocks) occurred for some of the farmers are shown in Table 8.

1998/99 SEASON

The trial was repeated in 1998/99 with the same set of farmers and the same treatments as in 1998/99 except that *Crotalaria* was undersown within the extra control plot.

2. Pest Management for Smallholder Field Crops

KEYNOTE ADDRESS

The changing face of pest management in Malawi

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ABSTRACT

Efforts to reduce the damage caused by insect pests and diseases in crops in Malawi started more than 60 years ago. However, since that time the numbers of pests and diseases have increased. Some are very destructive agricultural pests while others are of lesser importance. Early work in plant protection using pesticides was carried out mainly on cash crops, such as coffee, cotton and tobacco. Previous research projects in plant protection focused on pesticides and few other pest control strategies. Integrated pest management (IPM) systems involving even reduced pesticide use are not feasible for many smallholders in Malawi since they lack the resources to purchase chemicals. The smallholder farmers' use of pesticides has been limited to vegetable production and grain storage. Most smallholder farmers mainly use indigenous methods of pest control and the effectiveness of such methods is yet to be evaluated. To address concerns about environmental pollution and human health hazards, however, present plant protection projects aim to achieve sustainability by combining IPM with full farmer participation. At present, farmer involvement is a priority in the development of researchable areas and the dissemination of technical messages. The participatory approach has also revealed that soil fertility is the most important production constraint in the Farming Systems Integrated Pest Management (FSIPM) Project area. Current research to improve IPM strategies needs to incorporate indigenous knowledge. The future of integrated crop management in Malawi will involve an interdisciplinary approach bringing together plant protection, soil fertility, other production practices and the social sciences.

INTRODUCTION

Plant protection is as old as crop farming itself. Smallholder farmers have always tried to keep crop losses caused by pests and diseases as low as possible, using measures which appeared effective in the light of their state of knowledge. On a global scale, these losses, including post-harvest losses, are estimated as being equivalent to about one-third of the crops produced (GTZ, 1994). The advent of pesticides in the 1950s assisted in the production of export crops, such as cotton, tobacco and coffee. The use of insecticides such as DDT, dieldrin and aldrin was the order of the day in the 1960s. However, these pesticides are now among those pesticides – persistent organic pollutants (POPS) – which have been banned from agricultural use. As crop production expanded so the pests and diseases increased, and consequently, the use of pesticides expanded. Concerns over the increased use of pesticides have been expressed and some resistance of pests to pesticides has emerged, resulting in pest resurgence.

The 1990s have seen shifts in thinking and priorities in agriculture. Sustainability is now an important aspect in the agricultural agenda because of widespread environmental and human health risks posed by agro-chemicals. However, nowadays there is a conflict between agribusiness and those supporters of ecofarming/sustainable agriculture. Opponents of sustainable agriculture control much of the media and, therefore, their opinions dominate the debate. They assert that if farmers stop using chemicals (that they just happen to produce) then the world would starve (Tesfai, 1999). There is a recognition that agricultural research in the past has been more beneficial to resource-rich, rather than resource-poor farmers. In Malawi, it is not just a question of sustainable agriculture but sustainable livelihood and an agriculture that has to be both economically viable and ecologically sound. Crop protection for the future has to face the challenges posed in the 1990s, that of working within sustainable agricultural systems which will ensure the livelihoods of farmers, especially resource-poor farmers. Many agricultural systems today depend on pesticides for crop protection on a regular basis, but these can cause environmental contamination as well as loss of biodiversity. A number of different options for crop protection are available and the options employed should be those best suited to the agro-ecology of the country and for the benefit of farming communities; not only for commercial interests and profits. Some of these options include biological control, indigenous methods of pest management, cultural control, use of resistant crop varieties, biopesticides, regulatory functions and plant quarantine (Daudi, 1999).

The environment has been adversely affected in one way or another by the use of pesticides. The recent approach to reduce the build-up of pest populations is to use some non-chemical pest control measures, thereby reducing the amounts of pesticides applied and, in some cases, a total use of non-chemical control measures. Research projects have been carried out since the 1960s, and include projects on control of cotton pests, macadamia nut borer, larger grain borer, cassava green mite, biological control of cassava mealybug, coffee breeding and the present Farming Systems Integrated Pest Management (FSIMP) Project, all of them mainly investigating IPM approaches. Some regulatory approaches, such as the uprooting of cotton and tobacco stalks at prescribed dates, have been instituted to reduce carry-over of pests from one season to another.

This paper discusses the approaches that farmers have been using, i.e. indigenous methods of pest control, use of pesticides, regulatory methods, and farming systems IPM methods. It also discusses pests and diseases in general compared to other production constraints in the project areas of Blantyre Agricultural Development Division (ADD).

CONTROL OF PESTS AND DISEASES

FAO (1982) produced a catalogue of major and minor crop pests in Malawi. Since then many new pests and diseases have invaded the country. The most important ones are the larger grain borer (*Prostephanus truncatus*) (LGB) and grey leaf spot disease of maize, *Fusarium* wilt of pigeonpea caused by *Fusarium udum*, and sweet potato weevil (*Cylas puncticollis*). Other pests which have invaded and have increased in magnitude include the citrus woolly whiteflies in citrus in Mwanza and other citrus growing areas, red spider mites in tomatoes, banana weevil, *Cosmopolites* spp., banana bunchy top virus disease and banana sigatoka disease. Besides the normal use of pesticides in controlling the early and newly introduced pests and diseases, some new approaches to pest control have been implemented which have also caused changes to some of the pesticides used. For example, the control of *Sitophilus zeamais*, the maize weevil, has been through the use of Actellic (pirimiphos-methyl) 2% dust. However, this pesticide does not control LGB. Actellic Super has been recommended for the control of both LGB and maize weevils and consequently, the use of Actellic 2% dust has been phased out. There is also a change in the extension approach. Previously, the message to farmers was to store maize in cobs but LGB multiplies faster when maize is stored in cobs. The current recommendation is to store maize already shelled in bags treated with Actellic Super. The use of a biological control agent, *Teretrius nigrescens*, has been recommended especially for the control of LGB in its natural habitat. For control of *Fusarium* wilt disease, the use of resistant varieties has been recommended, one of which is ICP 9145. A biological control agent, *Cales noacki*, is effective in controlling citrus woolly whiteflies. For red spider mites, work is still going on in screening for resistance, biopesticides and pesticide screening. The recommendation for control of banana bunchy top virus disease is to uproot the infected plants together with the corms. Any re-growth has to be removed and the land left bare for 2 years while clean suckers are being multiplied. This operates alongside the prohibition on the importation of banana suckers, even in tissue culture. Cassava mealy bugs and cassava green mites are being controlled by biological control agents, such as *Apoanagyrus lopezi*

Table 1. Some of the findings and potential solutions to pest and disease control in Malawi developed over many years

Crop	Pest/disease problem	Solution and possible solutions
Maize	Larger grain borer	Shell maize, treat with Actellic Super and use of *Teretrius nigrescens* as a biological control agent
	Termite	Use of *kaselera* method, avoid banking
	Striga	Trap cropping, hand-pulling, extra weeding and use of inorganic fertilizers
	Grey leaf spot	Resistant varieties
	Streak virus	Resistant varieties
	Whitegrub	Seed dressing, varietal resistance
Cotton	Various pests	Pesticides, resistant varieties, regulatory control, monitoring, benefit threshold, and forecasting through pheromone traps
Banana	Bunchy top virus	Uprooting bananas for 2 years and then supply clean suckers
	Radopholus nematodes	Hot water treatment, chicken manure, paring and neem
Pigeonpea	*Fusarium* wilt	Resistant varieties, e.g. ICP 9145
Sweet potato	*Cylas* weevil	Crack sealing and vine selection
Tomato	Red spider mites	Resistant varieties, cultural control
	Root-knot nematodes	Resistant varieties, uprooting, rotation, use of *Pasteuria penetrans* as a biocontrol agent
Macadamia	Insect pests	Calendar spraying, IPM
Cabbage	Club root	Raising pH by liming, good soil drainage, crop rotation, general weed control, avoid using manure from animals fed with infected crop residues
Cassava	Mealybug	*Apoanagyrus lopezi* biological control agent
	Green mite	*Typhlodromalus aripo* biological control agent
Beans	Bean disease	Resistant varieties such as Napirila
Groundnut	Virus and rusts	Resistant varieties
Coffee	Coffee berry disease	Ruiru 11 resistant to CBD
		Cultural practices for pest control

Table 2. Some indigenous methods for pests and disease control

Indigenous methods	Comments
Weed control	*Striga* seed bank reduced. Some pests are also removed with weeds.
Garlic, chilli, soap and Mphanjobvu	Used for insect pest control in vegetable crops.
Mixed cropping	Results in heterogeneous host population that limits spread of pests and diseases.
Shifting cultivation	Prevents build-up of pests and diseases inherent in a continuous cultivation system.
Seed selection and drying	Seeds are selected which have survived pests and diseases. Drying prevents weevil damage.
Burning crop residues	Destroys the developmental and over-wintering instars of pests, thus reducing their population in subsequent seasons.
Hand picking	Mechanical crushing, practised with armyworm, grasshopper and locust.
Use of light traps	To attract nocturnal insect pests, such as grasshopper and locust.
Sticky bands	Around tree trunks to prevent caterpillars from climbing and destroying tree crops.
Tempting food	Traps placed in pits or large buried pots to kill rodents.
Scaring	Various devices, such as drumming, catapulting, human voice, scarecrows for birds, monkeys, locusts and grasshoppers have been used successfully.
Direct trapping	Rodents and monkeys.
Slurry of goats and sheep droppings	Used on foliage and stems of maize, pepper and cassava to deter these animals from grazing on crops.
Wood ash	Used in controlling ants destroying vegetables such as cabbage. Treatment of seeds and ware stock. Dusting of barns and granaries and then exposing to the sun for some time before storing new produce.
Tobacco leaf extracts	Used against destructive snails and other crawling pests.
Neem oil extracts	Used to prevent the moulting of locust and other insects.
Groundnut oil	Used to prevent weevil infestation and damage to stored stock and seed.
Rogueing and pruning	To remove infested and infected plants or branches.
Infested fruits	Removal and burying them to reduce inoculum build-up.
Bicycle spokes	Used to kill stem borers in coffee.

Source: MoAI (1996) and Nebane (1999).

and *Typhlodromalus aripo*, respectively. The selection of clean planting material is one of the IPM approaches in the production of cassava (Table 1). Diamond-backed moth is a serious pest of cabbage and *Bacillus thuringiensis* has been used to reduce infestation. Work is in progress to control cabbage club root disease and to date, raising soil pH has managed to reduce the incidence of the disease.

INDIGENOUS KNOWLEDGE OF PEST CONTROL

Man's knowledge of plant protection systems probably correlates with man's history of plant domestication. This knowledge has certainly evolved with man's increased sophistication, expansion of his cultivation base, and knowledge of pests and diseases. Thus over the years, man has made a conscious effort to protect his crops, however crude the methods, to enable him to face the challenges of survival and threats of famine. The intention has always been to reduce pest populations and disease incidence and severity to tolerable levels. Pests and disease forecasting is the backbone of successful pest management and entails a detailed knowledge of the biology and ecology of the pest and disease concerned. Accurate pest and disease forecasting cannot be easily achieved as it involves several natural parameters. The indigenous plant protection systems of the resource-poor, often illiterate, farmers draw upon past collective experience of pest occurrence, in which serious outbreaks are often attributed to the whims of the gods (Nebane, 1999).

There are many methods, which farmers have been using for a long time, to control pests and diseases, although there is no scientific basis and little documentation to support them. Placing maize, sorghum and other seeds on a platform above a fireplace hardens the kernels and weevils find it difficult to destroy them. Wood ash has been used to control pests in legume seeds since the ash interferes with egg laying. Other farmers have used natural pesticides extracted from trees such as Mphanjobvu, to control pests in vegetable crops, and neem has also been used as a pesticide. Crop rotation and intercropping have been used for many years for reasons besides controlling pests and diseases. Seed selection before planting has assisted farmers to discard infested and infected seeds, increasing seedling vigour in the new crop. Nurseries for vegetable production have been prepared by burning maize stalks to reduce soil pathogens such as nematodes. The removal of infested fruits, which drop to the ground, has significantly reduced populations of fruit flies in guava and citrus trees. Some farmers have used bicycle spokes to kill coffee stem borers in stems of coffee plants (Phiri, 1998).

All these control methods have assisted in planning some of the IPM strategies presently available. The agricultural extension staff of the Ministry of Agriculture and Irrigation provided information on pest control methods by holding a competition, which produced much useful information on indigenous pest control methods (MoAI 1996). Table 2 presents some indigenous methods of pest and disease control but the list is far from being exhaustive.

Indigenous plant protection technologies are more effective against insect pests than diseases, possibly because pests are more readily recognized by farmers, and the damage they cause is direct. Farmers can afford to use these methods although some of them are labour intensive. The efficacy of indigenous systems may not be easily quantifiable, although it can be qualitatively assessed or appreciated.

There has also been some confusion between the biology of the pest, particularly migratory pests, such as armyworm (*Spodoptera* spp.), and the myths that surround them. This has also contributed to a misunderstanding of the importance of pest control in the farming community.

For example, in some sections of Blantyre ADD, whenever, there is an invasion of armyworm, the villagers brew some traditional beer and dance for a few days to ask their ancestors to solve their current pest problem. The armyworm disappears by the time the farmers finish their rituals. In fact, the armyworm has pupated but the villagers think their prayers have been heard. Some farmers are now aware of the biology of the pest but others think they have supernatural powers enabling them to control the pest.

One farmer in Thyolo RDP, explained that his beans were not attacked by bean bruchids when his wife dipped her hand into the bag of stored beans. Consequently, to avoid any infestation, she is the only one to collect beans from the bags (probably it is a way of avoiding wastage by other people, including their children).

FARMERS' PERCEPTIONS OF PEST MANAGEMENT

It is interesting to note that for many years, farmers only appreciated the damage caused by migratory pests, such as armyworm, locusts and grasshoppers. To some farmers, reduction in yields is associated with production factors other than pests and diseases. For example, a wilting tomato plant is never associated with nematode damage.

Farmers from the project area of Mombezi and Matapwata Extension Planning Areas (EPAs), and also farmers from other parts of the country, have reported the decline in soil fertility as their major problem, rather than pests and diseases. This was manifested by a demand for fertilizers rather than pesticides by farmers in many parts of the country. Using

Table 3. Some of the projects in plant protection and their major findings

Project	Station	Some major findings
ARC (ODA) (before 1975)	Makoka	Pheromone traps. Monitoring and forecasting. Different insecticides used. Regulatory control measures by establishing dates for uprooting cotton stalks. Cotton varieties resistant to jassids.
Crop storage (ODA) (1970s)	Bvumbwe	Recommended the use of Actellic 2% dust for the control of *Sitophilus* weevils. Recommended the use of rat guards in granaries. Recommended mudded granaries for insect control.
Soil pests (DFID) (1990s)	Chancellor College	Termite control – *kaselera*. Crack sealing to control sweet potato weevil. Documented pests of pigeonpea. Documented nematodes associated with maize in Malawi.
MGPPP (GTZ) (1990–2002)	Chitedze	Biocontrol of LGB by use of *Teretrius nigrescens*. Use of Actellic Super; maize storage in bags (shelled) or in mudded granaries. Recommended cassava IPM. Work on tomato red spider mite/cabbage club root control in progress. Working on organizational changes in plant protection.
FSIPM (DFID) (1996–2000)	Bvumbwe	Control of whitegrub in maize through seed dressing. Control of termites in maize. Control of *Striga* in maize. Control of bean stem maggot and diseases in beans. Varieties of pigeonpea resistant to *Fusarium* wilt. Agricultural economics. Social anthropology to understand the behaviour of farmers in respect to pests and diseases.
ICRISAT (1980s)	Chitedze	Varieties of groundnut resistant to rust and virus.
Macadamia (ODA)(1980/90s)	Bvumbwe	IPM in macadamia pest control.
DARTS (continuous)	All major research stations	Recommended pesticides, resistant varieties, biological control, biopesticides, cultural pest control strategies, regulatory pest control and plant quarantine measures.
Coffee (FAO) (1990s)	Lunyangwa	Resistant variety, Ruiru 11, plus cultural practices.
Rice (ASC) 1990s	Mkondezi	Pesticide for the control of rice blast.
FAO (1995)	Bvumbwe	Pesticide draft bill and safe use of pesticides training.
EEC (1994)	Bvumbwe	Biological control of nematodes in tomatoes.

Table 4. Some of the constraints farmers face which have a direct influence on plant protection

Constraint	Implications
Labour shortage	Farmers failing to complete weeding.
Shortage of cash	No cash to purchase pesticides, sprayers and protective clothing to control pests and diseases.
Knowledge of pest/disease	Farmers fail to appreciate pest and disease damage, confuse with a problem of fertility.
Poor health of farmer	Farmers falling sick at the peak of farming operations, weeding and pest/disease control.
Illiterate	This problem cuts across many areas, e.g. farmers cannot read instructions.
Politics	Farmers not willing to follow some advice from extension workers on pest control, thinking the officer belongs to a certain political party.
Migration of working people to towns	Productive men leaving for town and yet they are the ones able to carry out control measures.
Climatic factors	May induce pest outbreak.
Poor marketing system	Farmers may not realize profits because of poor marketing systems. Sometimes not profitable to control pests and diseases.
Policing of laws	Plant protection acts or acts related to pest control are in place but there is no enforcement. Vendors end up selling obsolete or substandard pesticides.
Non-aggressive extension techniques	Extension staff having no messages to convince the farmers about new methods of pest control.
Lack of infrastructure	Farming might not be profitable if roads are impassable and the marketing system is not organized.
Hand hoe	Difficult to control all weeds at the right time and also one cannot progress much with farming using hand hoes.
Farmers not treating farming as business	Few farmers take farming as a business seriously like the tomato and potato growers in Dedza and Ntcheu districts who purchase pesticides and other inputs.
Few extension staff	Extension staff not reaching all farmers for plant protection messages.
Little money allocated to Ministry of Agriculture	Agriculture is the backbone of our economy, but insufficient funds are allocated to this Ministry; the Plant Protection Service is the least considered.
No subsidies for inputs and machinery	Spraying machines and fertilizers are expensive and this has a deleterious effect on crop production.

participatory methods, Orr and Jere (1999) confirmed that low soil fertility and low maize productivity are major causes of food insecurity among smallholders in the Shire Highlands. Consequently, deliberate efforts were made to address the fertility problem by using cheap sources of nutrients, such as *Tephrosia vogelii* and *Crotalaria* spp. Improving the health of plants through nutrition will make the plants more able to withstand attack by pests and diseases. Therefore, we should be looking at an integrated approach to increase crop production rather than solving one aspect of crop production in isolation (Orr, 1997).

The participatory approach was used in this project where all crop production activities were discussed with the farmers and the latter agreed on the way forward. This is the way forward rather than a top-down approach. However, client-oriented research is also being encouraged these days by other countries (Mbwaga, 1999). It is an approach that emphasizes stakeholders' involvement in research identification, allocation of resources and evaluation of new technologies. Client-oriented research is, therefore, demand-driven, reflecting the increased attention to technology that satisfies the well-defined needs of communities. The stakeholders in client-oriented research include extension officers, researchers, farmers and NGOs involved in agricultural production. Each of these stakeholder groups has a role to play in plant protection. The advent of Farmer Field Schools (FFS) in extending IPM strategies to the farming community is an extension of the participatory method that the FSIPM Project has been using.

Over the years, different approaches have been tried for pest and disease control. Different pesticides and other control methods have been tested and recommended for various crop pests and diseases. This has depended on donors and the general thinking on pest management approaches at any particular time (Table 3). Some of the donor projects concentrated fully on pest control, while other projects had approached the pest problem in a holistic way. For example, the Agricultural Research Council (ARC) project which was based at Makoka Research Station in the early 1970s, looked at all aspects of cotton production, including cultural methods, soil chemical and physical status, pesticide use, use of pheromone traps and various scouting techniques, while the macadamia project concentrated on macadamia pest control using calendar spraying. However, we must appreciate the problems farmers face and this may influence pest management. Farmers have numerous problems which are summarized in Table 4. If most of these problems are solved, then the farmer may be in a better position to appreciate the contribution of pest management. Some of the problems have to be solved by government while others are of local concern.

RECOMMENDATIONS

Indigenous knowledge systems in Malawi should be documented. Initially surveys should be carried out in all the ADDs to collect this information. Future research should concentrate on evaluating their effectiveness in pest and disease control and then incorporate them into IPM strategies.

There is need for training as part of human resource capacity building in the changing face of pest management. These training courses could be in the form of seminars, short courses and certificate training courses.

Demand-driven research is the way forward, i.e. when there is a problem, let us solve it. However, we should also be thinking about long-term programmes in plant protection. By analogy, research on computers began some 50 years ago and we are benefiting from the results now. Back then this research was not demand-driven. There is a lesson here for plant protection.

CONCLUSIONS

Many research projects in plant protection have developed various methods of pest and disease control and farmers have been involved in the implementation of some of these methods. Most smallholders have hardly used pesticides because of a lack of resources, unlike estate farmers who can afford to purchase them. The only instances where smallholder farmers have used pesticides are in vegetable production and maize storage. The general idea of IPM reducing pesticide application probably does not apply to Malawian smallholder farmers since their use of pesticides is minimal. However, smallholder farmers have been implementing IPM by using a mix of intercropping, cultural control methods, natural pesticides and indigenous knowledge methods. Therefore, more efforts should be made to assist smallholder farmers to reduce pest and disease build-up to increase crop production and productivity in Malawi. To achieve increased productivity, however, soil fertility has to be improved since this is a major constraint. Pests and diseases will continue to reduce the yields of both smallholder and estate farmers if proper control strategies are not put into operation.

Many control options are available but they need to be made available in a way that the extension personnel can use. We need to address the problems that farmers face in the production of crops with respect to plant protection. Government can solve some of the problems but farmers should not wait for government to assist them all the time. They have to be responsible for solving some of their own problems, particularly now liberalization and privatization are the order of the day. Indigenous knowledge systems have not been documented and this is an area where more resources should be used. Some of the indigenous strategies could be tested to determine their usefulness in future recommendations.

Donor assistance is, therefore, called for in this new area of research. We are living in an integrated world. As professionals in plant protection, we should not work in isolation, we have to integrate our activities with other disciplines including agronomy, crop physiology, soil fertility, social sciences (agricultural economics and social anthropology) and other disciplines in crop production to increase crop productivity. We need to understand the way in which farmers work, why they behave the way they do in decision-making with respect to plant protection. On a wider scale, collaboration with other projects, international agricultural research centres, training institutions, private investors and NGOs is necessary. This is a changing face of pest management in Malawi.

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DISCUSSION

P. W. Kabuluzi. Having noted that little money is allocated to the Ministry of Agriculture and Irrigation and that there are no subsidies for inputs for the improvement of crop production and protection, this seems to be a policy issue. How best can we advise the government on the improvement of funding on important agricultural programmes?

A. T. D. There is a need for a position paper for policy-makers on this issue. I hope that our Minister can convey our request to the Cabinet or Treasury.

M. M. Kayembe. The use of local products from plants (e.g. tobacco, neem, *Tephrosia*, etc.) as pesticides has been mentioned several times. You indicated that there is a need for documentation and research in this area. What is the department of research doing on this aspect? This should have been an area of research with the FSIMP Project. Why did the project not investigate this issue?

A. T. D. Very little work and documentation has been carried out in this area and donor funding is required. Probably if the FSIMP Project continued for another phase we would look at this subject and it would be an opportunity to consolidate our knowledge of these indigenous systems.

Cultural management of sweet potato weevil (*Cylas puncticollis*)

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ABSTRACT

An on-farm trial was mounted in Matapwata and Mombezi Extension Planning Areas (EPAs) in the 1998/99 season to test the efficacy of crack sealing in reducing the population of *Cylas* weevil and damage to sweet potato. In Matapwata, the results showed significant effects on mean yield, and the total weight of both clean and damaged tubers. In Mombezi EPA, crack sealing showed no significant effects on any of the variables assessed, either in *dambo* or upland zones. However, the treatments showed a consistent tendency to reduce yield in the upland area while showing positive effects on yield in the *dambo*. By disturbing the vines, crack sealing might have reduced the above-ground biomass and thus the capacity of sweet potato for photosynthesis, thereby reducing yields. Injury to roots from crack sealing during this period might have also impaired tuber development and reduced yields. In addition, because of high rainfall and low population levels of *Cylas* weevils, treatments might not have had the most appropriate conditions to demonstrate their potential benefits. Gains in yields in the *dambo* may have resulted from agronomic benefits associated with crack sealing, such as reduced weed competition and improved aeration and drainage due to frequent weeding. Farmers' perceptions about crack sealing as an integrated pest management (IPM) strategy for *Cylas* weevil were generally positive, but their main concerns were that it was labour-demanding and sometimes the benefits were not high enough to compensate fully for their investment in labour and time. However, economic analysis of the Chiradzulu *dambo* trial suggests that farmers could expect to gain, on average, in return for their investment in labour when they decide to change from their one weeding practice to two extra weedings (crack sealings).

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is the most second important root and tuber crop, after cassava, in Malawi. In Blantyre/ Shire highlands, it plays an increasingly important role in the smallholder farming system. National statistics show a nine-fold increase in production and doubling of yield (from 5 t to 10 t/ha) of sweet potato from 1993/94 to 1997/98 (FEWS, 1998). A study of sweet potato and smallholder food security in Blantyre/Shire Highlands (Mwale *et al.*, 1999a, b) revealed that this expansion is due to an increase in the area planted to sweet potato and increased average yields. The expansion in area planted is because of the substitution of sweet potato in place of other crops rather than the intensification of the farming system, while increased average yields reflects wider adoption of Kenya, a high yielding variety that is grown primarily for the market.

Crop losses from sweet potato weevil (*Cylas puncticollis*), however, are still a major production constraint in Malawi. Research has shown that a promising IPM approach is to encourage the adoption of cultural practices that prevent build-up of the pest and so reduce damage to economically acceptable levels. Sealing of cracks has been proved to be effective against *Cylas formicarius*. In Malawi, the Chancellor College Soil Pest Project successfully tested the method in Katuli EPA, Mangochi in 1993–95, although no detailed report of their results has been produced.

For the past two seasons, the FSIPM Project initiated a trial at Mangunda section in the Matapwata Extension Planning Area (EPA) to test the efficacy of sealing cracks of different sweet potato varieties to *Cylas* attack and also to test the resistance or tolerance of different sweet potato varieties to *Cylas* damage. Orr *et al.* (1998) reported a farmer diagnosis and evaluation of the trial. The conclusion was that crack sealing up to eight times was laborious and counter-productive owing to an adverse effect on yield despite a slight reduction in weevil infestation. In the 1998/99 season, a similar trial was mounted with the maximum number of sealings limited to three. A similar trial was mounted in Mombezi EPA in the 1998/99 season because diagnostic work there also showed a high incidence of *Cylas* weevil (about 35–45%, Ritchie (1999)). Only the Kenya variety of sweet potato was used in this trial.

CRACK SEALING TRIAL OBJECTIVES, DESIGN AND RESULTS

Trial design and treatment structure

The 1998 crack sealing trial was reviewed with farmers at a meeting in Mangunda on 24 August 1998 with five participating farmers. It was agreed at that meeting to repeat the experiment with only one variety, Kenya, and to use no more than three crack sealings/plot, which were drawn on a time line by farmers (treatments A, C, D, E). Farmers suggested that a single crack sealing (treatment C) should be timed to coincide with the second

Table 1. Treatment structure and timing of crack sealing

Treatment	Matapwata		Mombezi – upland		Mombezi – *dambo*	
	Planned dates	Actual	Planned dates	Actual	Planned dates	Actual
Median planting dates	2 February	2 February	27 January	27 January	4 March	4 March
A. FP	3 weeks after planting	3 weeks after planting	3 weeks after planting	3 weeks after planting	3 weeks after planting	3 weeks after planting
B. FP + 1 early sealing	7 weeks after planting	7 weeks after planting	–	–	–	–
C. FP + 1 late sealing	10 weeks after planting	10 weeks after planting	5 weeks after planting	7 weeks after planting	6 weeks after planting	7 weeks after planting
D. FP + 2 sealings	13 weeks after planting	13 weeks after planting	7 weeks after planting	9 weeks after planting	8 weeks after planting	9 weeks after planting
E. FP + 3 sealings	15 weeks after planting	15 weeks after planting	9 weeks after planting	11 weeks after planting	10 weeks after planting	12 weeks after planting

FP, Farmer practice.

sealing of the two treatments with two or more sealings. In Mangunda, an additional treatment was included in the experiment (treatment B) which was a single sealing on the same date as the first sealing of the two multiple sealing treatments (D and E). The agreed treatment structure for the trial in both Mangunda and Mombezi and the planned and actual times of operations are shown in Table 1. The on-farm trial in Mombezi was split into two zones, the *dambo* and the upland. Farmers plant sweet potato in the *dambo* later than in the upland zone to wait for improved water drainage. Generally, weevil infestation is also believed to be higher in the *dambo* than the upland.

The trial consisted of eight plots, each with six ridges. Each plot measured 5.4 x 5.4 m. In Mangunda, farmers' normal practice is to weed twice (at 3 and 7 weeks after planting) The second weeding is a form of *kukwezera*. In Mombezi, farmers normally weed sweet potato fields only once 3 weeks after planting. Farmers provided labour for crack sealing. At

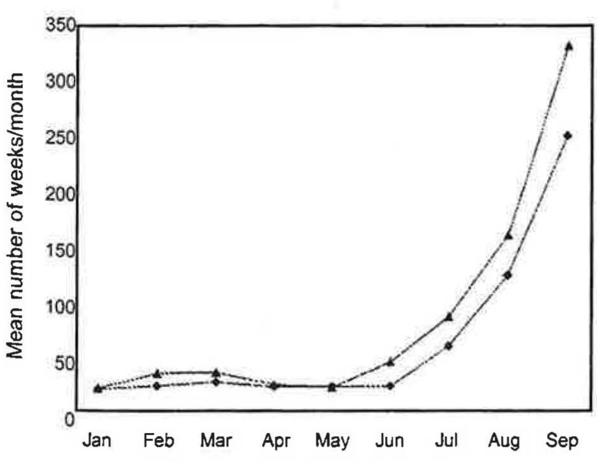

Figure 1. Pheromone trap catches of Cylas puncticollis, *Mombezi EPA, January–September; diamond, upland; triangle,* dambo.

harvest, the net plot of 4 ridges/sub-plot (4.8 x 3.6 m) was assessed. All the tubers from each net sub-plot were sorted into damaged and undamaged categories and weighed. Ten damaged tubers were chosen at random, dissected and the weevils counted. Farmers' perceptions about losses from weevil damage were also obtained by asking them about the alternative uses of tubers classified as damaged by the research team.

The population pressures of adult weevils available to attack tubers were also assessed using pheromone traps. Ten traps were set up in Mombezi EPA in Lidala and Chiwinja villages, five each in the *dambo* and upland zones. The traps were placed in sweet potato fields around the area where the trials were being conducted, no less than 50 m away from the experimental plot to avoid disruption of weevil attack on the crop.

Experimental results

Mombezi EPA

Weevil population dynamics for the Chiradzulu upland zone are shown in Figure 1. The population was low during this period of experimentation (27 January–15 May). The treatments may, therefore, not have had suitable conditions to show their potential benefits. In addition, the season generally experienced a high amount of rainfall as shown in Figure 2. Weevil population and damage are likely to be low in wet years.

Table 2 summarizes the statistical analysis for the main variables in the Chiradzulu upland zone. No treatment effects were found to be significant for any of the variables analysed. Crack sealing seemed to have a slight negative effect on yield. On a per hectare basis, average gross yields in the upland decreased from 6.092 t to 5.958 t, 5.893 t and 5.526 t, although they were not statistically different. By disturbing the vines, crack sealing may have reduced the above-ground biomass and thus the capacity of sweet potato for photosynthesis, thereby reducing yields. Sweet potato experiences active tuber enlargement from 6 weeks after planting until about the sixteenth week after planting (Bouwkamp, 1983). Injury to tubers from hilling-up during this period would impair tuber development and reduce yields.

Weevil population dynamics in the Chiradzulu *dambo* are also shown in Figure 1. The populations of weevils were slightly higher than in the upland zone, but still low enough not to create a sufficient condition to show the treatments' potential benefits. With the high rainfall during this season, the waterlogged environment in the *dambo* might not have been conducive to *Cylas* weevil activities.

The summary of the statistical analysis for the main variables in the Chiradzulu *dambo* is presented in Table 3. As in the upland, no treatment effects were found to be significant for any of the variables analysed. There was also no evidence of a farmer by treatment interaction. Crack sealing, however, showed some positive effect on sweet potato yields in the *dambo*. Total yields (clean weight + damaged weight) increased from 2450 t in the control to 3303 t, 3684 t and 3381 t with 1–3 crack sealings, respectively. These yield gains might have come from reduced weed competition that is a serious constraint to increased sweet potato yields. Most of the *dambo* in Chitera have star grass which is a difficult weed, requiring several weedings to eradicate. Again, frequent weeding may have helped loosen the soil, thus allowing sufficient air circulation and space for tuber enlargement. Without proper management, *dambo* soils tend to be hard and have poor air and water circulation, thus inhibiting tuber development.

Table 4 summarizes the statistical analysis for the main variables of field pea, usually grown as an intercrop with sweet potato in the *dambo*. No evidence was found to prove the research hypothesis that sealing would produce a reduction in the yield. There were no significant differences in any of the yield components of the pea crop regardless of the sealing treatment applied.

Matapwata EPA

Table 5 presents the summary of the statistical analysis for the main variables in Mangunda. Unlike in Chiradzulu, the trial results showed clear evidence of differences in mean yields (taken as total weight of tubers in the net plot, including clean and damaged tubers between treatments (P=0.009). The analysis of variance corrected the treatment effects for farmer's effect (P=0.001) and indicated farmer by treatment interaction (P=0.035). The latter indicates that treatments have different results depending on the farm where they were tested, i.e. the farmer by treatment interaction is different behaviour in carrying out the treatments depending on the farmer. There were two treatments that changed their relative performance depending on the farmer, i.e. farmer practice (FP) and one early sealing. Significant differences were also observed in the total weight of damaged tubers (P=0.008). However, there were no significant differ-

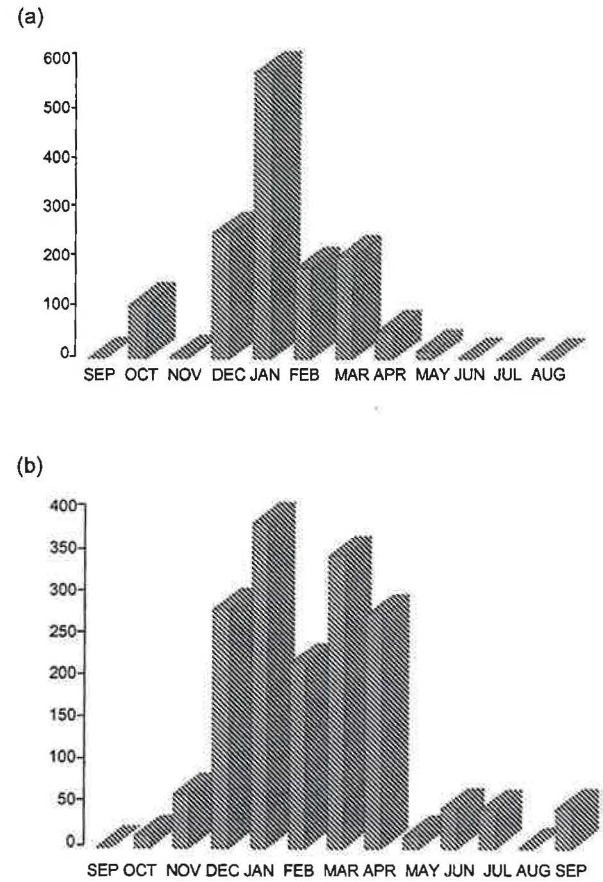

Figure 2. Rainfall pattern in Mombezi and Matapwata EPAs in the 1998/99 season. (a) Mombezi EPA; (b) Matapwata EPA, Mangunda.

ences for the percentages of damaged tubers. This implies that the overall level of damage was relatively similar for all treatments and was around 52%. Other variables that yielded significant differences between treatments were total clean tubers (0.012), and number of tubers suitable for home use only (P=0.023). The main pattern that emerges from this analysis was that the treatment 'farmer practice' was the one that consistently presented desirable results.

As in the Chiradzulu upland, sweet potato yields decreased with crack sealing. Previous studies have shown that while two crack sealings at 4 and 6 weeks after planting increases yields, hilling-up after 6 weeks did not further reduce weevil damage but instead tended to reduce yields (Pardales *et al.*, 1987). Table 1 shows that crack sealing in the trial was carried out from 7 to 11 weeks for the upland on-farm trial, from 7 to 12 weeks for the *dambo* trial and from 10 to 15 weeks in Mangunda.

Farmers' evaluation of the on-farm trial

Sixteen of the seventeen trial farmers were met individually soon after the sweet potato harvest to elicit their final comments about the trial using a check-list of questions. The individual interviews focused on two main areas:

Table 2. Summary of the analysis for the main variables in the Chiradzulu upland sweet potato trial

Treatment	Net plot stand count	No. clean tubers in net plot	Total weight of clean tubers (kg/ha)	Weight of 20 clean tubers (kg)	No. damaged tubers from net plot	Total wt damaged tubers (kg/ha)	Weight of 20 damaged tubers (kg)	Total damage score from sample (TOP)	Total damage score from sample (BOTTOM)	Ground cover by vines in net plot (%)	Damage wt/total wt tubers (%)	Total yield (clean + damaged tubers) (kg/ha)
Farmer practice	54.42	117.6	4769	1.84	21.6	1323	1.60	32.2	30.3	65.00	24%	6092
FP + 1 late sealing	56.92	106.6	3872	1.79	34.3	2085	1.74	35.2	37.1	63.33	33%	5958
FP + 2 sealings	55.58	87.5	3853	1.97	32.6	2040	2.14	44.6	41.2	65.42	35%	5893
FP + 3 sealings	56.50	93.3	3844	1.84	34.5	1682	1.74	40.1	40.1	64.17	31%	5526
P (treat)							0.296	0.076	0.072	0.913	0.179	0.942
	0.75	0.198	0.545	0.895	0.07	0.152						
SE (diff)	6.03	36.2	18538	0.605	13.1	886	0.705	11.7	10.4	7.67	0.125	2337
P (treat*farmer)							0.792	0.942	0.777	0.73	0.706	0.998
	0.179	0.861	0.965	0.322	0.413	0.359						
df in the error term	24	24	24	24	24	24	24	24	24	24	24	24

Table 3. Summary of the analysis for the main variables in the Chiradzulu *dambo* sweet potato trial

Treatment	Net plot stand count	No. clean tubers from net plot	Total weight clean tubers (kg/ha)	Weight of 20 clean tubers (kg)	No. damaged tubers from net plot	Total weight damaged tubers (kg/ha)	Weight of 20 damaged tubers	Ground cover by vines in net plot (%)	No. saleable tubers*	No. tubers suitable for home use only*	No. useless tubers (rejected)*	Total damage score, TOP[1]	Total damage score, BOTTOM[1]	Mean no. *Cylas*/ tuber	Percentage damage[a]	Total yield
Farmer practice	49.67	77.8	1577	1.058	33.1	873	0.942	37.5	6.42	13.7	13.33	35.5	33.33	1.42	0.349	2450
FP + 1 late sealing	50.58	66.6	1741	1.542	50.7	1780	1.517	46.3	10.5	20.7	19.42	41.2	35.42	2.53	0.445	3303
FP + 2 sealings	50.33	72.2	2397	1.333	40	1288	1.308	44.2	11.33	17.1	11.75	38.6	33.5	1.37	0.395	3684
FP + 3 sealings	52.33	70.9	2098	1.558	42.3	1534	1.375	45.4	10	21.3	10.67	39.4	35.83	2.67	0.405	3381
P (treat)	0.803	0.875	0.285	0.056	0.294	0.157	0.092	0.176	0.466	0.605	0.143	0.603	0.882	0.172	0.423	0.097
S.E. (diff)	6.85	33.6	375.7	0.475	22.1	973	0.548	10.3	8.01	15.5	9.6	10.3	9.51	1.8	0.139	485
P (treat*farmer)	0.712	0.932	0.695	0.898	0.655	0.957	0.89	0.986	0.988	0.897	0.086	0.2	0.772	0.612	0.3	0.824
df in error term	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	22

*As perceived by farmer. [1]Total damage score for sample (TOP) (1–5 scale). [1]Total damage score for sample (BOTTOM) (1–5 scale). [a]Weight of damaged tubers/total yield.

Table 4. Summary of analysis for the main variables of field pea in Chiradzulu *dambo* sweet potato trial

Treatment	Net plot stand count	No. plants with pods/plot	Total pod weight (kg/ha)	Biomass weight (kg/ha)
Farmer practice	138.7	136.5	949	452
FP + 1 sealing	136.3	133.7	720	360
FP + 2 sealings	145.7	142.8	1097	520
FP + 3 sealings	144.5	141.8	886	351
Significance probability (treat)	0.845	0.85	0.116	0.069
SE (diff)	21.2	20.8	142	65
Significance probability (treat*farmer)	0.253	0.229	0.051	0.034
df in error term	12	12	12	12

- their knowledge about the sweet potato weevil and its means of dispersal and nature of damage, plus their perception of the severity of damage;
- their evaluation of crack sealing as a strategy for controlling the weevil.

Farmers were shown samples of damaged tubers for their perceptions about the causes and severity of damage. Two levels of damage were shown: the primary damage that may be rejected or accepted by farmers for specific purposes such as eating or selling and the advanced damage. Farmers' perceptions of the severity of weevil damage and their evaluation of crack sealing as a strategy for controlling weevils are shown in Table 6 and summarized below.

Knowledge about *Cylas* weevil and farmer perception of its damage to sweet potato

About 63% of farmers said that primary level damage on sweet potato is caused by the weevil (*nakafumbwe*), 31% said other soil pests and borers were responsible and only one farmer said he did not know what caused the damage.

About 56% of farmers perceived advanced level damage on sweet potato to be caused by weevils, while 25% thought it was caused by other soil pests.

Only 19% of the farmers associated the advanced level damage with heavy rains. About 69% of farmers said that the eggs found in the tubers were laid by weevils that entered through the soil cracks which occur as the sweet potato plant starts to develop tubers. Only 31% of farmers said they did not know how the eggs were found inside the tubers.

Lightly damaged sweet potato was said to be used for food in 57% of cases and can be sold, though at low prices in 43% of cases.

Advanced level damaged tubers are left in the field in 43% of cases, 29% fed the tubers to livestock, 14% cooked them while 14% made into *makaka* (sliced and dried for future use).

Objective of sealing cracks, observed damage levels, yield and tuber size differences

To check if farmers understood the objective of the trial, each farmer was asked what s/he thought was the purpose of sealing ridges in sweet potato fields.

About 70% of the farmers said sealing the cracks helped to prevent the weevil from damaging sweet potato, while 18% said crack sealing helped to reduce weed infestation and another 12% said it helped to loosen the soil for good tuber development.

About 75% of farmers observed more weevil damage on tubers from plots that were unsealed than from the sealed plots. While 19% said more damage was observed in the sealed plots than in the unsealed plots, only one farmer (6%) said he observed no difference in the level of damage between sealed and unsealed plots. There were no differences in perceptions about observed damaged tubers between the *dambo* and upland trial farmers. They both perceived that more damage was observed on unsealed plots than sealed plots.

About 56% of farmers observed larger tubers on sealed plots than on unsealed plots while 25% thought small tubers were harvested from sealed plots than unsealed plots. About 19% observed no difference in the size of tubers.

About 69% of farmers observed higher yields in plots that were sealed than from the unsealed plots. Plots that were sealed were perceived to have given higher yields because frequent weeding reduced weed competition and sealing of ridges helped to loosen the soil, thus improving air and water circulation which was good for tuber development.

Only 18% observed smaller yields from plots that were sealed than unsealed. The argument for this observation was that frequent crack sealing makes the ridges compact and tubers cannot expand. Only 12.5% of farmers observed no difference in yield between sealed and unsealed plots.

Table 5. Summary of the analysis for the main variables in the Mangunda sweet potato trial

Treatment	Net plot stand count	No. clean tubers in net plot	Total weight clean tubers (kg/ha)	Weight 20 clean tubers (kg)	No. damaged tubers from net plot	Weight 20 damaged tubers (kg)	No. saleable tubers	No. tubers suitable for home use only	No. useless tubers (rejected)	Total damage score from sample (TOP)	Total damage score from sample (BOTTOM)	% ground cover by vines in net plot	% damage: damage weight/total weight tubers	Total yield (clean + damaged tubers) (kg/ha)	Total weight damaged tubers (kg/ha)
Farmer practice	51.6	109.7	11360	4.28	70.8	4.32	48.4	23.7	0.2	39.2	33.8	67.0	46.6	19381	8021
FP + 1 early sealing	46.4	85.2	7917	4.42	80.4	4.98	43.1	35.4	2.0	36.1	34.7	71.0	57.8	17517	9601
FP + 1 later sealing	49.5	88.8	8142	3.69	74.9	4.47	35.6	35.3	2.5	40.6	38.5	63.0	53.6	15839	7697
FP + 2 sealings	46.4	78.0	7824	4.24	78.5	4.39	46.6	27.2	3.5	37.5	33.6	66.5	51.2	14988	7164
FP + 3 sealings	47.4	98.5	8212	3.63	69.8	4.09	51.4	17.8	0.3	35.7	33.6	55.5	50.4	14502	6291
P (treat)	0.515	0.246	0.012	0.603	0.405	0.813	0.167	0.023	0.065	0.826	0.677	0.083	0.158	0.009	0.008
Approx. standard error difference	7.15	27.6	1932	1.27	14.6	1.87	12.8	9.8	2.9	10.6	10.5	9.7	9.7	2530	1631
P (treat*farmer)	0.854	0.681	0.027	0.808	0.098	0.715	0.002	0.043	0.009	0.975	0.906	0.615	0.335	0.035	0.002
df in error term	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

Table 6. Farmers' evaluation of crack sealing trial

	No.	%
Cause of primary damage on sweet potato		
Sweet potato weevil (*nakafumbwe)*	10	62.5
Other soil pests	5	31.25
Don't know	1	6.25
	16	**100**
Cause of advanced damage on sweet potato		
Sweet potato weevil (*nakafumbwe*)	9	56.25
Other soil pests	4	25
Due to heavy rains	3	18.75
	16	**100**
How eggs entered the sweet potato tubers		
By weevils which entered through the cracks	11	68.75
Don't know	5	31.25
	16	**100**
Alternative uses of primary damaged tubers		
Cooked for food	12	57.14
Sold at low prices	9	42.85
	21	**100**
Alternative uses of advanced damaged tubers		
Cooked for food	3	14.29
Sliced into *makaka*	3	14.29
Fed to livestock	6	28.57
Left in the field	9	42.86
	21	**100**
Purposes for sealing ridges in sweet potato field		
To prevent weevil from damaging sweet potato tubers	12	70.59
Keeps field free of weeds	3	17.65
Loosens soil to improve air and water circulation for tuber growth	2	11.76
	17	**100**
Observed yield differences in the trial plots		
High yields in sealed plots	11	68.75
Lower yields in sealed plots	3	18.75
No yield differences	2	12.5
	16	**100**
Observed tuber sizes differences in trial plots		
Big tubers in sealed plots	9	56.25
Small tubers in sealed plots	4	25
No differences	3	18.75
	16	**100**
Observed damaged tubers differences in trial plots		
More damage on unsealed plots	12	75
More damage on sealed plots	3	18.75
No difference in damage	1	6.25
	16	**100**
Perceived benefits of crack sealing		
Helps prevent weevils from damaging tubers	11	35.48
Keeps field free from weeds	9	29.03
Loosens soil for tuber expansion	11	35.48
	31	**99.99**
Disadvantages of crack sealing		
Labour demanding	12	75.0
Disturbs tuber development and sometimes damages tubers	3	18.75
Disturbs other intercrops such as field pea	1	6.25
	16	**100**
Perceived best number of crack sealings		
None	1	6.25
One	2	12.5
Two	6	37.5
Three or more	7	43.75
	16	**100**
Number of crack sealings household willing to do		
None	1	6.25
One	3	18.75
Two	5	31.25
Three or more	7	43.75
	16	**100**

Table 7. Labour requirements for crack sealing, Mombezi EPA – *dambo* and upland zones

	Mean time (min)/plot		Mean time (man-hours/ha)	
Treatment	**Upland**	***Dambo***	**Upland**	***Dambo***
Farmer practice	–	–	–	–
FP + 1 late crack sealing	26.22	38.18	149.86	218.22
FP +2 crack sealings	21.22	29.23	121.28	167.07
FP +3 crack sealings	19.08	19.10	109.05	109.17

Farmers' evaluation of crack sealing as a strategy for preventing weevils

Perceived benefits of crack sealing and constraints to adoption

Farmers thought crack sealing is beneficial because it helps to prevent weevils from damaging tubers (35% of responses), helps to keep the field free of weeds (30%), loosens the soil to improve air and water circulation for tuber development (35%).

About 75% of farmers perceived labour constraints to be the major limiting factor that could prevent farmers from adopting the technique. Another 16% thought crack sealing, carried out at a period when the sweet potato has already started developing tubers, damages the tuber and disturbs its development. One farmer said crack sealing disturbs the field pea that is grown as an intercrop in the *dambo*.

Farmers' willingness to carry out crack sealing

Farmers were asked what they perceived as the best number of crack sealings from the experience they had with the trial. About 44% recommended three crack sealings, 37.5% thought two crack sealings would be sufficient taking into consideration the competing demands of labour. Only one farmer thought crack sealing was not necessary because he was not convinced it yielded much higher benefits than his own practice of weeding twice.

Asked how many crack sealings each farmer would be willing to do with their own available labour in the household, 43.75% of the farmers said they would seal cracks on at least three occasions. Another 31.25% of the farmers said they could seal up to three times while 18.75% said one sealing was enough for them.

As a group, the participating trial farmers also discussed the results of the trial at the farmer to farmer/researchers and extension staff farewell meeting that was held at Bvumbwe on 4 November 1999. This meeting also gave them an opportunity to share their results with other collaborating farmers, extension staff as well as researchers. Three important elements were the centre of the presentation that the farmers made at the farewell workshop. They all agreed that crack sealing reduces damage from weevils but has a negative effect on tuber size. Crack sealing, when carried out at an advanced stage of plant growth, disturbs tuberization and sometimes damages the tubers themselves in the process. The practice is labour demanding and sometimes the benefits are not high enough to compensate for the time and effort required by the farmer.

Farmers' vs researchers perceptions of losses – a quantitative approach

Summaries of the statistical analysis for alternative uses of damaged tubers in Chiradzulu *dambo* (Table 3) and Mangunda (Table 5) suggests that farmers' perceptions of the severity of damage from weevils is lower than the researchers' perceptions. Farmers generally accepted what were classified as 'damaged tubers' to be of some use, notably, for sale or home use. In Mangunda, the number of damaged tubers that farmers considered to be useless was almost negligible in all the treatments. Thus, the economic threshold level required for farmers to adopt crack sealing as a pest management strategy for *Cylas* weevil is higher than that of researchers and may vary depending on the use of sweet potato.

ECONOMICS OF CRACK SEALING

Labour requirements

The trial design, as stated earlier, required a total of up to 3 crack sealings/farmer. Labour requirements for crack sealing on trial plots were timed. In the upland zone, a total of 26 observations were made for the first crack sealing, 15 observations for the second crack sealing and 12 observations for the third crack sealing. In the *dambo*, a total of 17 observations were made for the first crack sealing, 24 observations for the second crack sealing and 12 observations for the third crack sealing. Times per unit area were weighted according to the type of labour used (1.0, male; 0.8, female) and converted to a per hectare basis. Table 7 shows the labour requirements for crack sealing which differed by zone, reflecting the differences in texture between *dambo* and upland soils.

Dominance analysis for crack sealing trial

Dominance analysis is an initial examination of the costs and benefits of each treatment. It is carried out by first listing the treatments in order of increasing variable costs. Any treatment that has net benefits less than or equal to those of

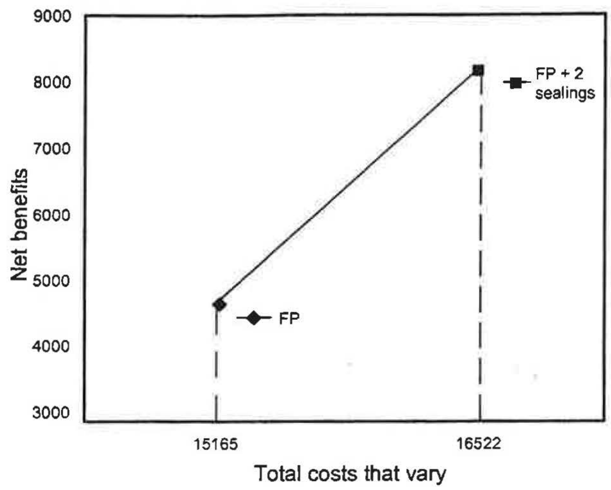

Figure 3. Net benefit curve, sweet potato crack sealing trial – dambo *zone.*

a treatment with lower variable costs is dominated. The costs and benefits for this analysis are taken from Tables 10–12.

In the *dambo,* the third crack sealing is dominated because it has lower net benefits than the second, yet with higher variable costs. In the upland zone, the other three crack sealing treatments (I, 2, 3), however, all have lower net benefits but higher variable costs than the FP treatment and, therefore, do not merit any further economic analysis. In the *dambo,* treatment two (one crack sealing) and four (three crack sealings) are also dominated because they have higher costs but lower net benefits than farmer practice.

The net benefit curve

Dominance analysis eliminated treatments two and four but has not provided a firm recommendation. To compare treatments farmer practice and two crack sealings requires a further analysis. Farmers are generally interested in seeing the increase in costs required to obtain a given increase in net benefits. This is comparing the costs that vary with the net benefits. This is best illustrated by plotting net benefits of each treatment against total costs that vary – the net benefit curve (Figure 3). As only non-dominated treatments are included in the net benefit curve, its slope will always be positive.

Marginal rate of return

The net benefit curve shows the relation between the costs that vary and the net benefits for the treatments. This helps to clarify the reasoning behind the calculation of marginal rates of return, which compare increments in costs and benefits between pairs of treatments. The purpose of marginal analysis is to reveal just how net benefits from an investment increase as the amount invested increases. If farmers who grow sweet potato in the *dambo* invest MK1357 in two additional crack sealings, they will recover MK3463 (the costs that vary have already been subtracted from the gross field benefits, plus an additional MK4746).

An easier way to express this relationship is by calculating the *marginal rate* of return, which is the marginal net benefit (i.e. the change in net benefits) divided by the marginal cost (i.e. the change in costs), expressed as a percentage (Table 9). The marginal rate of return from changing from the existing farmers' cultural management practice to adding two additional crack sealings is, therefore:

(MK 19 064-MK15 601)/(MK 16 522-MK 15 165)

=3463/1357=2.5519

=255.19%

This means that for every MK1/ha invested in one additional crack sealing, farmers can expect to recover the MK1 and an additional MK255.

The foregoing positive marginal rate of return (255%) confirms the visual evidence of the net benefit curve.

The marginal rate of return is a characteristic of the change from one treatment to another. It indicates what farmers can expect to gain, on average, in return for their investment when they decide to change from one weeding practice to more than one. In the above case, for farmers who plant sweet potato in the *dambo,* adopting two additional crack sealings implies a 255% rate of return.

However, a decision cannot be taken without knowing what rate of return is acceptable to farmers. It is necessary to estimate a minimum rate of return. For the majority of situations, experience and empirical evidence have shown that the minimum rate of return acceptable to farmers will be between 50% and 100%. This is an estimate for crop cycles of 4–5 months. If this range of 50–100% serves as a useful guide in this trial, farmers would be advised to adopt *two*

Table 8. Dominance analysis, sweet potato crack sealing trial

Treatment	Total costs that vary (MK/ha)			Net benefits (MK/ha)		
	Mangunda	Chiradzulu upland	Chiradzulu *dambo*	Mangunda	Chiradzulu upland	Chiradzulu *dambo*
Farmer practice	4747	4195	15165	29333	10112	4746
FP + early sealing	5253	–	–	18498 d	–	–
FP +1 late sealing	5805	4747	15874	18621 d	6869 d	869 d
FP+2 crack sealings	6288	5230	16522	17184 d	6329 d	8209
FP +3 crack sealings	6702	5648	16997	17934 d	5884 d	3457 d

Table 9. Marginal rate of return analysis, crack sealing trial in the *dambo*

Treatment	Total costs that vary	Marginal costs	Net benefits	Marginal net benefit	Marginal rate of return (%)
FP	15 165		4746		
		1357		3463	255.19
FP + 2 crack sealings	16 522		8094		

Table 10. Economic analysis for crack sealing – upland farmers, Mombezi EPA

Variable	Farmer practice	FP+ 1 late crack sealing	FP + 2 crack sealings	FP + 3 crack sealings
Benefits				
Yield (kg/ha)	6092	5958	5893	5526
Clean yield	4769	3872	3853	3844
Adjusted yield (kg/ha)	3815	3098	3082	3075
Unit price (MK/kg)	3	3	3	3
Gross benefits (MK/ha)	**11445**	**9294**	**9246**	**9225**
Variable costs				
Materials (MK/ha)	0	0	0	0
Vines	1251	1251	1251	1251
Labour requirements (h/ha)	768	768	768	768
Labour for intervention (h/ha)	0	144	270	378
Total labour requirements (h/ha)	768	912	1038	1146
Unit price (MK/day)	23	23	23	23
Imputed labour cost (MK/ha)	2944	3496	3979	4397
Total variable costs (MK/ha)	**4195**	**4747**	**5230**	**5648**
Net benefits				
Return over variable costs (MK/ha)	**10112**	**6869**	**6329**	**5884**
Benefit:cost ratio (full-cost basis)	2.73	1.96	1.77	1.63
Benefit:cost ratio (cash-cost basis)	9.15	7.43	7.39	7.37
Gross returns to labour (MK/day)	89.41	61.14	53.45	48.30

additional crack sealings on top of their normal weeding practice which is carried out 3 weeks after planting.

Although treatment three (two sealings) had the highest net benefits and yield, it is not always the case that farmers have to invest in treatments that give the highest benefits and yields. Farmers should continue to invest as long as the returns to each extra unit invested (measured by the marginal rate of return) are higher than the cost of extra units invested (measured by the minimum acceptance rate of return).

CONCLUSION

Technical evaluation of crack sealing

As in the 1997/98 trial, crack sealing showed no significant effects in reducing the population of *Cylas* weevil or damage to sweet potato tubers in Mombezi EPA. This might have been because of the high rainfall and low population levels of *Cylas* weevils experienced during the season. The treatments might not have had high enough weevil populations to show their potential benefits. Instead, crack sealing tended to reduce yields. In the *dambo*, however, crack sealing showed positive effects on both total yield and total weight of clean tubers. This might have been a result of reduced weed competition and particularly improved air circulation and drainage due to frequent weeding. Poor drainage and severe weed competition have negative effects on the performance of any crop. These conditions are all prevalent in the *dambo*. In Mangunda, the trial yielded significant effects with respect to mean total yield, total weight of clean tubers and total weight of damaged tubers.

Treatments were also found to be significant in reducing the number of damaged tubers that farmers considered useless. The farmer by treatment interaction showed also significant effects (P=0.035) which indicates different behaviour in the treatment effects depending on the farmer. Farmers' perception assessment also showed significant effects of treatments on the numbers of damaged tubers that could be used for home use.

Again as in Chiradzulu upland, crack sealing in Mangunda persistently showed a negative effect on yield. By disturbing the vines, crack sealing may have reduced the aboveground biomass and thus the capacity of sweet potato for photosynthesis, thereby reducing yields, and may also have disturbed tuber development more directly.

Farmer evaluation of the trial

Farmers generally understood the rationale of crack sealing as a management strategy for *Cylas* weevil. They believed

Table 11. Economic analysis for crack sealing – *dambo* farmers, Mombezi EPA

Variable	Farmer practice	FP+ 1 late crack sealing	FP + 2 crack sealings	FP + 3 crack sealings
Benefits				
Sweet potato yield (kg/ha)	2450	3303	3684	3381
Clean yield	1577	1741	2397	2098
Adjusted clean yield (kg/ha)	1262	1393	1918	1678
Unit price* (MK/kg)	3	3	3	3
Gross benefits (MK/ha)	**3786**	**4179**	**5754**	**5035**
Field pea yield (kg/ha)	949	720	1097	886
Adjusted clean yield (kg/ha)	759	576	877	708
Unit price (MK/kg)	20	20	20	20
Gross benefits (MK/ha)	15180	11520	17540	14160
Total gross benefits (MK/ha)	19911	16743	24731	20454
Materials† (MK/ha t)	0	0	0	0
Vines (MK/ha)	1251	1251	1251	1251
Field pea seed (MK/ha)	10855	10855	10855	10855
Labour requirements‡ (h/ha)	798	798	798	798
Labour for intervention (h/ha)	0	186	354	480
Total labour requirements (h/ha)	798	984	1152	1278
Unit price[a] (MK/day)	23	23	23	23
Imputed labour cost (MK/ha)	3059	3768	4416	4891
Total variable costs (MK/ha)	**15165**	**15874**	**16522**	**16997**
Net benefits				
Return over variable costs (MK/ha)	**4746**	**869**	**8209**	**3457**
Benefit:cost ratio (full-cost basis)	1.31	1.05	1.50	1.20
Benefit:cost ratio (cash-cost basis)	1.64	1.38	2.04	1.69
Gross returns to labour (MK/day)	35.68	5.30	42.75	16.23

*Unit price of sweet potato is price that prevailed during the survey period. Price for main crop sweet potato.

†The vine cost was calculated as follows: the recommended planting density requires 37 000 plants/ha using vines of 25–30 cm (guide to agricultural production, MAI 1994). One 30-cm vine weighs 20 g. Thus total wt/ha is 751 kg. Farmers buy vines normally in bags that carry 50 kg of fertilizer. One such bag is estimated to weigh 30 kg. The market price of such bags in 1998/99 was MK30–MK50. Taking the higher rate, the cost of vines/ha was MK1251.

‡Labour for land preparation, planting, farmers' cultural practice and harvest were obtained from secondary sources but the additional crack sealing was timed during actual operation in the on-farm trial plots.

[a]Wage rate for male estate labourer, 1998/99, Mombezi EPA, working 6 h/day.

Table 12. Economic analysis for crack sealing – Mangunda, Matapwata EPA

Variable	Farmer practice	FP + 1 early sealing	FP + 1 late crack sealing	FP + 2 crack sealings	FP + 3 crack sealings
Benefits					
Yield (kg/ha)	19381	17517	15839	14988	14502
Clean yield	11360	7917	8142	7824	8212
Adjusted yield (kg/ha)	9888	4334	6514	6259	6570
Unit price (MK/kg)	3	3	3	3	3
Gross benefits (MK/ha)	**27264**	**19002**	**19542**	**18777**	**19710**
Variable costs					
Materials (MK/ha)	0	0	0	0	0
Vines (M/ha)	**1251**	**1251**	**1251**	**1251**	**1251**
Labour requirements (h/ha)	912	912	912	912	912
Labour for intervention (h/ha)	0	132	276	402	510
Total labour requirements (h/ha)	912	1044	1188	1314	1422
Unit price (MK/day)	23		23	23	23
Imputed labour cost (MK/ha)	3496	4002	4554	5037	5451
Total variable costs (MK/ha)	**4747**	**5253**	**5805**	**6288**	**6702**
Net benefits					
Return over variable costs (MK/ha)	**22517**	**13749**	**13737**	**12489**	**13008**
Benefit:cost ratio (full-cost basis)	5.74	3.62	3.37	2.99	2.94
Benefit:cost ratio (cash-cost basis)	21.79	15.19	15.62	15.01	15.76
Gross returns to labour (MK/day)	148.14	79.00	69.37	57.02	54.89

that crack sealing reduced the level of weevil damage in the trial and they expressed their willingness to practise the technique because they said it also has other associated benefits like keeping the field free from weeds and loosening the soil for improved air and water circulation. Their main concern, however, was that crack sealing is labour demanding.

Farmers' acceptance of what are technically considered damaged tubers was also high for sweet potatoes that are used either for home use or for sale. This may have an effect in influencing the eventual uptake of the technology.

Economics of crack sealing

No further economic analysis was done for Mangunda and Chiradzulu because all the crack sealing treatments were associated with higher costs than FP and yet with low net benefits. The economic analysis of the Chiradzulu *dambo* trial showed that farmers can expect to gain, on average, in return for their investment in extra labour when they decide to change from their one weeding practice to two extra weedings (crack sealings).

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DISCUSSION

J. Sutherland. What proportion of the sweet potato crop is grown in *dambos* in the Shire Highlands? How was the opportunity costs for labour arrived at in the economic analysis of crack sealing?

B. W. The proportion of sweet potato varies from area to area, but in Mombezi EPA a large proportion of *dambo* is used for sweet potato because generally maize does not do well here. The wage rate was the labour wage taken from neighbouring estates (i.e. MK23) – opportunity cost.

Costs and benefits of seed dressing as a pest management strategy for whitegrubs in Blantyre/Shire Highlands

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ABSTRACT

This paper reports the results of three seasons of on-farm trials (1996/97, 1997/98 and 1998/99) of potential pest management strategies against whitegrubs attacking smallholder intercropped maize in Blantyre/Shire Highlands. Farmers in Chiradzulu North Extension Planning Area (EPA) were found to have adopted the practice of seed dressing maize with Sevin (carbaryl 85% WP) which they claimed reduced pre- and post-germination plant destruction by adults of the black maize beetle, *Heteronychus licas,* in valley bottom clay soil areas (*dambos*). A trial was mounted in 32 *dambo* fields using Sevin at dose rates of 7 g and 14 g/kg of maize seed, as a pest management strategy for whitegrubs (principally *Heteronychus,* but also larval stages of *Schizonycha* spp.). Sevin seed dressing had a significant negative effect on maize yield at the higher dose rate (P=0.051). There was no beneficial effect on germination success and a significant negative effect in Matapwata at the higher dose rate (P=0.027). Whitegrub numbers at harvest were not reduced by Sevin and in fact were increased at the lower dose rate (P=0.038). In Chiradzulu (but not Matapwata), the higher dose of Sevin significantly reduced the number of early deaths by whitegrub by five times (P=0.001). Sevin treatment had no positive effect on yield and actually reduced yield significantly at the higher dose. It is probable that a heavy dose of Sevin and a high whitegrub population are needed to justify farmers' belief in the benefits of Sevin, since in the absence of whitegrub attack it reduces maize yields by 300–600 kg/ha.

In 1997/98 Gaucho 70 WS (imidacloprid) (5 g/kg of seed) was used instead of Sevin as a maize seed dressing on both *dambo* and upland fields since sampling indicated that upland fields had higher numbers of scarabaeid larvae. Levels of plant deaths by whitegrub were low overall (23% plots <2% plants). Maize yields were consistently higher in upland than in *dambo* fields and there was some indication of reduced yield at high soil potassium levels in the presence of seed dressing. Seed dressing significantly increased maize yields in upland fields by about 500 kg/ha (P=0.001) but in *dambo* fields the gain (*c.* 120 kg/ha) was not significant. Whitegrub numbers at harvest were reduced by seed dressing in *dambo* fields (P=0.001), but not in upland fields. Five whitegrub species collected from farmers' fields were identified as: *Heteronychus licas* Klug, *Schizonycha fusca* Brenske, *S. salaama* Kolbe, *S. angustula* Moser and *Trochalus exasperans* Peringuey. *Aserica* sp. and *Anomala* sp. were only identified to genus level. The *Schizonycha* species complex was the most prevalent and found in both EPAs, while *Heteronychus licas* was potentially the most serious maize pest in its adult stage in the Chitera *dambo* in Mombezi EPA.

During the 1998/99 cropping season, an on-farm trial was undertaken with nine farmers to assess the effects of seed dressing with Gaucho-T as a cheaper alternative to Gaucho 70 WS, and the incorporation of *Tephrosia vogelii* leaves in the ridge before planting on whitegrub numbers and maize yields. Seed dressing and incorporation of *Tephrosia* leaves significantly (P<0.05) increased maize yield though further analysis revealed that the beneficial effect was only realized in Chiradzulu upland fields. However, *T. vogelii* also significantly increased the numbers of whitegrubs in farmers' fields, contrary to expectation, given the insecticidal properties of *Tephrosia*. Despite the high cost of Gaucho, it appears that farmers with upland fields in Chiradzulu could achieve a satisfactory marginal rate of return (201%) using Gaucho as a maize seed dressing.

INTRODUCTION

The Farming Systems Integrated Pest Management (FSIPM) Project, financed by the UK Department for International Development (DFID) and the Government of Malawi, and based within the Department of Agricultural Research and Technical Services (DARTS) at Bvumbwe Research Station, has been conducting on-farm trials and investigations to develop appropriate pest management strategies for major pests of maize, bean, pigeonpea and sweet potato which can be extended to resource-poor farmers in Blantyre/Shire Highlands Rural Development Programme (RDP) area of Blantyre Agricultural Development Division (ADD). The initial crop focus of the project was determined by a Stakeholder Workshop held in June 1996 which also highlighted particular key pests (Ritchie, 1996). The rationale for the selection of specific Extension Planning Areas (EPAs) within the RDP and specific villages within those EPAs has been documented by Ritchie (1997).

Economic importance of whitegrubs

Surveys by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) during the 1986/87 growing season found whitegrubs to be the major pest of groundnut in areas receiving more than 1000 mm of rain annually,

Table 1. Whitegrub species found in farmers' maize fields in Mombezi and Matapwata EPAs

Species	Family	Subfamily
1. *Heteronychus licas* (Klug)	Scarabaeidae	Dynastinae
2. *Schizonycha fusca* Brenske	Scarabaeidae	Melolonthinae
3. *Schizonycha salaama* Kolbe	Scrabaeidae	Melolonthinae
4. *Schizonycha angustula* Moser	Scarabaeidae	Melolonthinae
5. *Trochalus exasperans* Peringuey	Scarabaeidae	Melolonthinae
6. *Aserica* sp.	Scarabaeidae	Melolonthinae
7. *Anomala* sp.	Scarabaeidae	Rutelinae

while termites were the most serious pests in areas with lower rainfall (Wightman and Wightman, 1994). The Chancellor College Soil Pests Project conducted surveys of soil insect pests in farmers' fields in the 1990/91 and 1991/92 seasons. It recorded whitegrubs as the second most damaging soil insect pest of maize (after termites) in 1990/91, while *Schizonycha* sp. was the most prevalent pest of vegetative groundnuts (Khonga, 1997; Logan *et al.*, 1995; Soil Pests Project, 1992). Between 29 and 38 species of scarabeid beetles were thought to be involved in crop damage but adults and juvenile stages of most individual species were not identified.

Several meetings were held with separate groups of men and women farmers in the selected villages to discuss their perceptions of the major pests of their crops and possible control methods. Whitegrubs, termites, cob rot and *Striga asiatica* were perceived by farmers as the most serious field pests of maize. With the exception of cob rot, all the field pests were perceived as increasing in severity. Farmers also used a wide range of control methods, several of which (e.g. the use of Sevin (carbaryl) seed dressing for whitegrub control) were innovative farmer practices.

The perceptions of farmers were consistent within and between Matapwata and Chiradzulu and were also similar to the views of the group of professionals and experts assembled at the Stakeholder Workshop. However, there was one major exception to this general agreement, i.e. whitegrubs, which were identified as the most important pest of maize in both Chiradzulu and Matapwata, although not ranked as a major pest by participants at the Stakeholder Workshop. This farmers' opinion receives some support from the findings of the Soil Pests Project (1992).

IDENTIFICATION OF WHITEGRUBS

There is relatively little published work detailing the species making up the whitegrub fauna in smallholder farmers' fields. A study was therefore undertaken (Mzilahowa, 1999) to identify the whitegrub species affecting maize intercropping systems in Matapwata and Chiradzulu (Mombezi) North EPAs.

Sampling was carried out in fields of 61 farmers who participated in the 1997/98 main trial. Refer to Abeyasekera, p. 28, for the full experimental design and plot layout. Sampling was done three times (in January, March and June) in the net plots. The adult beetles collected were preserved dry and sent to the International Institute of Entomology, UK for identification.

Table 1 shows the species of scarabaeid beetles found attacking maize in farmers' fields. Five species of scarabaeid beetles, *Heteronychus licas, Schizonycha fusca, S. salaama, S. angustula,* and *Trochalus exasperans* were identified, a further two species, *Anomala* sp. and *Aserica* sp., were identified to genus level. They belonged to three subfamilies: Dynastinae, Melolonthinae and Rutelinae. The genus *Schizonycha* was the most prevalent and occurred across both EPAs (Table 2).

The scarabaeid, *Heteronychus licas* (Klug), one of several related species commonly referred to as black maize beetle, is a potentially serious pest of maize in its adult stage. In the 1995/96 cropping season there was an unusual outbreak of this pest which forced some farmers to abandon their maize fields in the Chitera *dambo* in Mombezi EPA.

Table 2. Occurrence of whitegrub species in farmers' maize fields in Mombezi and Matapwata EPAs

	Mombezi EPA		Matapwata EPA		
Species	Chiwinja	Lidala	Kambuwa	Magomero	Total
Heteronychus licas	+	–	–	–	1
Schizonycha fusca	+	+	+	+	4
Schizonycha salaama	+	+	+	+	4
Schizonycha angustula	–	–	+	–	1
Trochalus exasperans	–	–	–	+	1
Aserica sp.	–	–	+	+	2
Anomala sp.	–	–	–	+	1
Total	3	2	4	5	14

MAIZE WHITEGRUB TRIAL 1996/97

Context and objectives

Technical options for whitegrub IPM include cultural control, crop resistance, biological control and selective use of pesticides. A participatory rural appraisal (PRA) in Chiwinja village (Chiradzulu North EPA) in 1996, found that a small group of innovative farmers had adopted the practice of treating maize seed with Sevin (Carbaryl) WP formulation (85%) against whitegrubs. Respondents indicated that the technique, which involved soaking seed, draining and mixing it with the insecticide, had been highly effective in killing beetles and reducing damage. In 1996/97, the effect of seed dressing maize with Sevin on whitegrubs was assessed in a multi-factorial experiment across 32 *dambo* fields in four villages in two EPAs.

The 1996/97 main intercrop trial was conducted with 64 farmers in four villages in two EPAs. This trial was set within the maize/pigeonpea/bean intercropping system with relay cropping of bean or field pea which is the commonest cropping system within the Blantyre/Shire Highlands. The objectives and design of the experiment have been detailed by Ritchie *et al.* (1997).

In addition to evaluation of several IPM strategies relating to pigeonpea and bean, there were two IPM objectives relating to maize:

- evaluation of a modified *kaselera* system (in upland fields in Matapwata) and weeding without banking at the second weeding stage (in upland fields in Chiradzulu) to reduce lodging of mature maize by termites;
- evaluation of seed dressing for the reduction of whitegrub damage to maize; the quantity used and the method followed was as close as possible to the farmers' own practice.

The advantages of combining trials of pest management strategies for the different crops within one on-farm experiment were listed by Ritchie *et al.* (1997). These include the fact that the approach mirrors the actual farming system; interactions between different pest management strategies and resource competition can be detected and obviated; and logistics are simplified by dealing with a limited area and farmer group; a factorial design cuts replication and reduces plot numbers and associated labour and expense.

To gain detailed information about the performance of maize varieties in relation to termites and whitegrubs, a replicated on-station monocropped varietal maize trial was mounted at the Veterinary Research Station at Thuchila. The results from this trial were analysed and reported by Abeyasekera (1998) and relevant conclusions are reported below.

Treatments and experimental design of 1996/97 trial

The maize treatment factors were:

- whitegrubs (seedling attack) – *dambo* only (Chiradzulu and Matapwata)
- seed dressing with Sevin (85% WP formulation) (level 1: 7 g/kg seed)
- seed dressing with Sevin (85% WP formulation) (level 2: 14 g/kg of seed)
- control: no seed dressing.

These treatments were a subset of a range of pest management strategies that were carried out for the overall intercrop farming system. During 1996/97, the main trial within a maize/pigeonpea/bean intercropping system involved 64 farmers with one plot in each farm under an intervention treatment and a second plot managed by the farmer according to his/her own practice. In view of the trial objectives to investigate two treatment factors for maize (one at 2 levels, one at 3 levels), two for pigeonpea (each at 2 levels), five for bean (each at 2 levels), a large number of treatment combinations resulted. The experiment was designed to ensure that any 'economic' type response made in the overall system could be analysed to take account of the full range of strategies tested within the experiment. The design was, therefore, set up as an incomplete factorial design with a fractional replicate of a 2^8 factorial experiment in four blocks, each having 16 plots, i.e. 64 experimental plots in total, 1 plot/farmer being used as the experimental unit.

The design was planned to ensure that all relevant 2-factor interactions could be estimated from the data. The 1996/97 design as originally proposed, together with a list of the full range of treatment factors used in the trial, appear in Abeyasekera, p. 28. The design is discussed in greater detail by Abeyasekera (1998) and is shown on p. 29. In addition to the 64 research plots, each farmer had a 'farmer's plot' in the same field where they implemented their own management practices using their own inputs. During the trial, variation in maize height and yields in research plots were found to be closely correlated with variation in the adjoining farmer's plot. This meant that farmer's plot data could be used as a covariate in the analysis which served to account for some inter-farm variation and reduced the residual variance.

Results for the management of whitegrubs in maize using Sevin

In 1996/97, the effect of seed dressing with Sevin on whitegrub was masked by the low fertility of the plots and the effects of waterlogging which led to many fields being abandoned. As a result no significant beneficial effect of seed dressing was observed, while at the higher dose rate, there was a significant negative effect on both maize yield (P=0.051) and on maize plant height (P=0.022).

The Thuchila on-station maize variety trial showed that Masika (Synthetic C) had the least number of plants killed by whitegrubs, significantly fewer than MH17 (P=0.004). However, Masika suffered significantly worse early mortality from other causes than MH17 (P=0.018 to 0.025). There were no other significant effects and further varietal testing for whitegrub resistance did not appear to be justified.

Data on plants killed by whitegrubs and other pests and diseases during the season were scanty because many plots were abandoned due to waterlogging. However, data on the numbers of live and dead plants on just a few of the initial sampling occasions were extracted and the germination stand count of maize plants in the 1996/97 season determined by taking the maximum, over the first two sampling occasions, of the sum of live plants and plants dead up to (and including) that occasion.

Analysis of germination stand count

Data on germination stand count were analysed, allowing for other sources of variation, e.g. variation due to EPA differences. There was insufficient evidence to indicate that germination stand count was influenced by the Sevin seed dressing treatment factor or by EPA. However, the analysis indicated that the effect of Sevin varied across EPAs (P=0.088). Further analyses were, therefore, carried out to compare germination rates across different levels of seed dressing within each EPA (Table 3). In Chiradzulu, germination rates were not significantly different. However, in Matapwata, there was some evidence that using the higher dose of Sevin (14 g) leads to a reduction in the germination stand count.

Table 3. Predicted mean germination stand count under different levels of seed dressing

Sevin treatment factor	Sample size*	Germination stand count	
		Chiradzulu	Matapwata
No seed dressing	8	305	312
7 g Sevin/1 kg seed	12	298	297
14 g Sevin/1 kg seed	12	316	272
Control vs 7 g Sevin		P = 0.683	P = 0.416
Control vs 14 g Sevin		P = 0.541	P = 0.027

*ANOVA, d.f. = 26.

Whitegrub numbers at harvest

At harvest, whitegrubs were found associated with damaged plants in 8 out of 16 plots. The numbers of whitegrubs found on 20 damaged plants were recorded. These data were subjected to a generalized linear modelling procedure with a Poisson error structure, allowing for EPA differences. The results showed some evidence that whitegrub numbers were higher on average for plots with 7 g Sevin/kg seed compared to control plots (P=0.038). There was insufficient evidence to indicate a difference in whitegrub numbers between control plots and plots with 14 g Sevin/kg seed (P=0.168). The predicted mean numbers of whitegrubs on 20 damaged plants are shown in Table 4 across different levels of seed dressing. These data provide little evidence to support the use of Sevin for the control of whitegrubs.

Whitegrub numbers in early part of season

Although several plots were abandoned due to flooding, plant mortality due to whitegrub had been recorded in the early part of the season. The number of plant deaths due to whitegrub, recorded at the first five sampling occasions, were analysed using a generalized linear model with Poisson errors. The analysis showed strong evidence of differences in the mean numbers of plant deaths due to whitegrubs across the Sevin treatment factor and across EPAs (P<0.001). There was also strong evidence of an interaction between these two factors (P<0.001). Further analyses revealed that the Sevin effect was not apparent in Matapwata. However, in Chiradzulu, the higher dose of Sevin led to a significant reduction in the mean number of plant deaths by whitegrub. Without this high dose of Sevin, the mean number of plant deaths was about five times higher, either without seed dressing or with a 7 g dose of Sevin. The results are summarized in Table 5.

Table 4. Predicted mean numbers of whitegrubs in 20 damaged plants

Sevin treatment factor	Sample size	Mean numbers of whitegrubs
No seed dressing	8	0.750
7 g Sevin/1 kg seed	9	2.000
14 g Sevin/1 kg seed	11	1.455
Control vs 7 g Sevin		P = 0.038
Control vs 14 g Sevin		P = 0.168

Table 5. Predicted mean number of plants killed by whitegrub, early in the season

Sevin treatment factor	Mean number of plants killed	
	Chiradzulu	Matapwata
No seed dressing	22.75	2.00
7 g Sevin/1 kg seed	22.50	3.00
14 g Sevin/1 kg seed	4.67	2.17
Control vs 7 g Sevin	P = 0.303	P = 0.367
Control vs 14 g Sevin	P < 0.001	P = 0.859

Raw data summaries for maize grain weights (kg/ha) and usable grain weights (kg/ha)

Table 6 gives simple summary data for maize grain weights and usable grain weights. Sample sizes are also included. Note that the true seed dressing effect cannot be judged from these summaries since they have not been adjusted to allow for other sources of variation.

Maize yields modelled (including yields recorded as zeros)

The two yield responses, i.e. the total grain yield (kg/ha) and the usable grain yield (kg/ha), were subjected to analysis of variance models, allowing for EPA differences and variation due to the other treatment factors. Each farmer had only one research plot, hence farmers formed the replicates for analysis. However, the yield from the farmer's own plot was used to account for some of the large variability between farms. The analysis showed insufficient evidence

Table 6. Mean grain weight (kg/ha) by EPA and use of seed dressing

	Sample size		Grain weight (kg/ha)		Usable grain wt (kg/ha)	
EPA	Chiradzulu	Matapwata	Chiradzulu	Matapwata	Chiradzulu	Matapwata
No seed dressing	4	3	162	597	131	539
7 g Sevin/1 kg seed	4	5	74	139	59	113
14 g Sevin/1 kg seed	5	6	106	578	92	479
Mean (or total)	(13)	(14)	114	425	94	361

Table 7. Predicted mean maize yields (kg/ha) under different levels of seed dressing

Sevin treatment factor	Grain yields (kg/ha)	Usable grain yields (kg/ha)
No seed dressing	390	338
7 g Sevin/1 kg seed	349	312
14 g Sevin/1 kg seed	208	164
Control vs 7 g Sevin	$P = 0.610$	$P = 0.746$
Control vs 14 g Sevin	$P = 0.038$	$P = 0.046$
ANOVA residual df	12	12

for an EPA effect, but several of the bean treatment factors were found to have an influence on maize yields. The Sevin seed dressing treatment factor showed only a marginal effect (P=0.082 for grain yields and P=0.087 for usable grain yields). However, further analysis revealed a significant effect at the 5% level for the difference in mean maize yields between the control plots and plots which had 14 g Sevin/kg seed (Table 7). There was no evidence of a difference between control plots and plots with 7 g Sevin/kg of seed.

Data that had been recorded as missing did not enter the analysis above. However, some of these missing data could effectively be regarded as zero observations since they arose when the farmer abandoned plots and grew another crop because of poor maize yields. Re-analysing the data with such missing records replaced by zero values gave similar results as above. The yields were poorest for plots having a 14 g dose of Sevin seed dressing.

Maize yields modelled (excluding yields recorded as zeros)

An analysis similar to the above was undertaken with the non-zero yield records. The sample sizes for this analysis are shown in Table 8 for total grain yields. For usable grain yields, the total number of non-zero values was 12 for Matapwata since one farmer's crop rotted and yield was very low.

Table 8. Distribution of farmers with non-zero yields

EPA	Chiradzulu	Matapwata	Total
No seed dressing	2	2	4
7 g Sevin/1 kg seed	2	5	7
14 g Sevin/1 kg seed	4	6	10
Total	8	13*	21

*One farmer's grain rotted, so only 12 farmers in Matapwata had usable grain yields.

Model predictions for mean maize yields across different levels of seed dressing are shown in Table 9. The means here vary in much the same way as those shown in Table 7. However, results here must be treated with slightly more caution since the small sample sizes resulted in only 7 d.f. for estimating the residual variation.

Conclusions on management of whitegrubs using Sevin seed dressing

These conclusions apply only to farmers growing maize in *dambo* areas, since only *dambo* fields were used in the trial. All results emerging from yield data analyses, except the raw summaries, demonstrate a systematic reduction in maize yields with increasing doses of Sevin used as a seed dressing for maize. The mean yield difference between control plots (no seed dressing) and plots with 14 g Sevin/1 kg seed was estimated to be 182 kg/ha for grain yields (95% confidence limits range from 12 to 352 kg/ha) and 173 kg/ha for usable grain yields (95% confidence limits range from 4 to 343 kg/ha). The very wide confidence intervals for the reduction in mean maize yields is not surprising since the residual variation in this trial has been determined in relation to farmer-to-farmer variation. Despite this high level of variation, it is interesting that the results still demonstrate some evidence of a reduction in mean yields with the application of Sevin seed dressing.

In the 1996/97 season, many farmers lost all their yield because of flooding. The analysis was, therefore, repeated using only the non-zero yield data. Although the sample sizes

Table 9. Predicted mean maize yields (kg/ha) under different levels of seed dressing

Sevin treatment factor	Grain yields (kg/ha)	Usable grain yields (kg/ha)
No seed dressing	637	560
7 g Sevin/1 kg seed	457	397
14 g Sevin/1 kg seed	320	261
Control vs 7 g Sevin	$P = 0.144$	$P = 0.244$
Control vs 14 g Sevin	$P = 0.022$	$P = 0.050$
ANOVA residual df	7	7

that then resulted were less than adequate for definitive conclusions to be made, the results obtained were similar. Mean yield differences between control plots and plots with 14 g Sevin/1 kg seed were 317 kg/ha for grain yields (95% C.I. = (62, 572) and 300 kg/ha for usable grain yield (95% C.I. = (0,600).

Farmers who use Sevin seed dressing claim that the use of the dressing leads to better plant emergence by killing the whitegrub at the initial stages of seed growth. However, in Matapwata, where whitegrub incidence was low, Sevin seed dressing appeared to lower germination rates. In this EPA, the lower dose of Sevin reduced the germination stand count by about 5% (a non-significant reduction), while the higher dose of Sevin reduced the germination stand count (significantly) by about 12%.

The overall incidence of plant death by whitegrubs was much lower in Matapwata (<1%) than in Chiradzulu (about 6%). The data did not demonstrate any beneficial effects of seed dressing where the incidence was low. However, in Chiradzulu, the mean number of plants killed by whitegrubs was about five times higher in plots without seed dressing or with a low dose of seed dressing compared to plots with the higher dose of seed dressing. It is possible that farmers' claim of the effectiveness of Sevin applies only when the whitegrub populations are large. However, the results here do demonstrate that, although Sevin can be effective in significantly reducing whitegrub populations, the effects of dressing in the absence of whitegrubs can be serious and lead to reductions in maize yields by as much as 300–600 kg/ha.

MAIN INTERCROP TRIAL 1997/98

Treatment factors

Maize IPM trials in the 1997/98 season were a follow-up to trials conducted in the 1996/97 season. The more expensive but less toxic alternative seed dressing, Gaucho (imidacloprid), which is sold elsewhere in Africa specifically for whitegrub control, was used instead of Sevin. The experiment was conducted both in *dambo* fields (as for 1996/97) and in upland fields because it had been established in 1996/97 that larval whitegrub attack occurs throughout the area, and also because there is known to be an anti-feedant effect of Gaucho on termites which it was hoped would be detectable on upland farmers' trial plots.

Farmer evaluation of IPM strategies carried out by Jere (1997) using semi-structured interviews was hampered by the complex experimental design and because each farmer saw only one treatment combination and, therefore, could not observe the full range of treatments on their fields. In some cases, farmers were unsure of the intended effect of a strategy.

The design of experiments for the 1997/98 season was specifically intended to ensure that most of the proposed combinations of management practices would be visible to each farmer on one or more of the four experimental plots on his/her farm. In addition, there was a radical reduction in the number of treatment combinations involved (2 for maize, 1 for pigeonpea and 1 for bean), focusing attention on those interventions most likely to have a significant effect which could be evaluated by farmers.

Four treatment factors were included in the trial. For maize, one factor, i.e. seed dressing with Gaucho, was used for the management of whitegrubs; and one factor, i.e. *mbwera* or no *mbwera* (in Matapwata), and weeding with banking or without banking (in Chiradzulu North) was used for the control of termites. Thus for maize, the treatment factors (effectively three factors) were:

for whitegrubs:

- seed dressing with Gaucho 70 WS vs no seed dressing

for termites:

- *mbwera* tillage in Matapwata (+ weeding without banking) vs weeding and banking without *mbwera*
- weeding with banking at second weeding in Chiradzulu North vs weeding without banking.

On bean and pigeonpea, only varietal tolerance was investigated. In both cases, four varieties were used, including a local variety as a check. The yield and damage responses for these intercrops were analysed separately and are not considered further in this paper. There were no significant interactions between maize treatments and intercrop varieties.

Distribution of farmers

Sixty-one farmers were included in the 1997/98 main intercrop trial. Each farmer had four plots on his/her farm with each plot having one of the proposed treatment combinations. The distribution of farmers across zones, villages and EPAs is shown in Table 10.

Table 10. Distribution of farmers across villages and land types

Land type (zone)	Chiradzulu		Matapwata		
	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	11	6	8	5	30
Upland	5	12	7	7	31
Total	16	18	15	12	61

Table 11. Mean values for four maize yield parameters according to land type and treatment factors

Treatment factor		No.	Usable grain weight (kg/ha) *Dambo*	Usable grain weight (kg/ha) Upland	Mean height of plants at harvest (m) *Dambo*	Mean height of plants at harvest (m) Upland	Average weight/ cob (kg) *Dambo*	Average weight/ cob (kg) Upland	Average number cobs/plant *Dambo*	Average number cobs/plant Upland
Seed dressing	Yes	120	1299	2701	1.74	2.03	0.093	0.145	0.755	0.939
	No	118	1180	2174	1.72	1.96	0.095	0.138	0.752	0.925
Banking	Yes	175	1429	2404	1.79	2.01	0.105	0.142	0.827	0.928
	No	63	630	2532	1.53	1.97	0.060	0.141	0.522	0.942
Mbwera	Yes	54	1309	2109	1.74	1.87	0.112	0.138	0.896	0.923
	No	54	1522	2243	1.75	1.83	0.121	0.140	0.927	0.946

Design layout

The general form of the experimental design used for the 1997/98 main intercrop trial was that of a randomized block experiment with a factorial treatment structure of 4 units/ farm forming a block. Factorial combinations between treatment factors were allocated to the incomplete blocks so that all important 2-factor interactions could be estimated. The design layout (unrandomized) for farms in each village and by zone (*dambo*/upland) and the treatment structure used can be seen in Abeyasekera, p. 28.

In each farm two plots had maize seed dressing while two did not. Where banking and *mbwera* were applied, two plots were banked, two were left unbanked, *mbwera* was done on two of the four plots.

Maize harvest data

Four yield responses were considered for analysis:

- usable grain weight (kg/ha) adjusted for stolen cobs and moisture content;
- mean height (m) of 10 randomly selected plants from the net plot at harvest;
- average weight per cob (kg), i.e. ratio of the weight of all cobs at harvest to the number of cobs;
- average number of cobs per plant = number of cobs/net plot stand count.

The means under each of the treatment factors across zones are shown in Table 11. Results demonstrate a beneficial effect due to seed dressing in upland fields with respect to usable grain weight and an improvement in grain yields with banking in *dambo* fields. *Mbwera* appears to have little effect except for a possibly poor effect in the *dambo* zone.

It is important to note that the summary data presented above make no allowances for other sources of variation that reside in the data such as the farmer-to-farmer variability, variation due to zones and EPA, etc. Investigation of the effect of the intervention treatments must take these sources of variability into account in order to provide information about the true performance of the maize crop under the different treatments. Such an analysis is presented below.

To study the treatment effects more formally by appropriate statistical procedures, two components of the analysis must be recognized:

- investigating maize yield responses at the farmer level relative to the farmer-to-farmer variation;
- investigating the effects of seed dressing, banking and use of *mbwera*, all of which were applied at the plot level within farmers' fields, hence these factors were investigated relative to the 'within farmer' variation.

Each of these analyses and corresponding results are discussed below.

Farmer level analysis

The major factors and variates likely to influence farmer-to-farmer variation are:

- EPA;
- zone, i.e. whether farmers fields were in a *dambo* or upland area;
- socio-economic cluster groupings of farming households as developed by Orr *et al.* (199) who used a number of socio-economic parameters to produce 'clusters' of farm households with shared characteristics (e.g. access to *dimba*, burley farmers, stable male-headed households, stable female-headed households, vulnerable households with low maize-provision ability);
- soil nutrient measurements, i.e. nitrogen, phosphorus, potassium, calcium, magnesium, zinc, pH and percentages of organic matter, sand, silt and clay.

Two measurements of soil nutrients were made on the research plot area within each farm. One measurement was made on a composite sample of 3–5 top-soil samples taken within 15 cm of the surface; these were referred to as ridge samples. A second measurement was made on a composite sample of 3–5 sub-soil samples taken at a depth of more than 15 cm from the soil surface; these were referred to as furrow samples.

Regression analyses, with EPA, zone and cluster as factors (grouping variables), were used to investigate the possible influence of these factors and the soil nutrient measurements on each of the yield response variables, averaged over the four plots in each farm. The soil nutrient measurements were included, in turn, as either ridge values, furrow values or combined values, the latter being an average between ridge and furrow values. The analysis was repeated using the mean from plots with seed dressing and then using the mean from plots without seed dressing.

The results (Table 12) show evidence of a strong zone effect, i.e. strong evidence that maize yields differ between *dambo* and upland areas with a better performance in the uplands. There was also some evidence of a zone by EPA interaction, except with respect to usable grain weight for seed-dressed plots, and an effect due to the availability of potassium in the soil in seed-dressed plots. The latter effect varied according to whether the fields were in *dambo* or upland areas. Further analyses demonstrated that the potassium by zone effect for seed-dressed plots was caused largely by records at Chiwinja village in *dambo* areas in the Chiradzulu EPA. About eight observations showed a negative linear pattern, giving some indication that for seed-dressed plots, increasing levels of potassium gave lower grain yields. The apparently strong potassium effect for the number of cobs/plant must be treated with some caution since the low significance probability was largely due to just three observations giving very low maize yields under high levels of potassium in village Chiwinja (Figure 1).

The effect of the socio-economic measurement factor cluster was also investigated but did not contribute significantly to variation in maize yield responses after accounting for EPA and zone differences.

Yield analysis

In the plot level analysis, treatment factors applied at the plot level were investigated. These were the application of seed dressing, banking and the use of *mbwera*. The interactions of these factors with zone and EPA differences were also investigated. *Mbwera* was relevant only within Matapwata and so the analysis involving *mbwera* was restricted to those farmers in the Matapwata EPA. Banking was generally practised in the Chiradzulu *dambo* areas, so

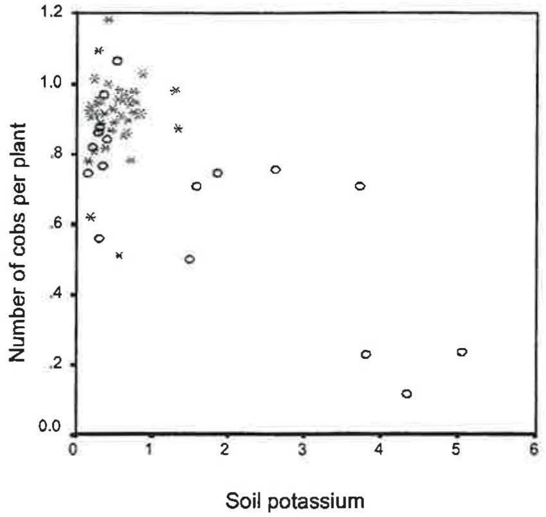

Figure 1. Effect of soil potassium on the number of cobs/plant; circles, Chiwinja (n=17)*; stars, other villages* (n=44)*.*

again the analysis involving banking was restricted to the remaining areas.

In the analysis, clear differences were found in maize yield responses between plots which had seed dressing and those that had not (P<0.001). This difference, favouring plots with seed dressing, was mainly due to the substantially greater yields (by about 500 kg/ha) in the upland areas compared to the *dambo* areas; the increase in maize yields under seed dressing in *dambo* areas was only about 120 kg/ha (Table 13). The latter was not a significant difference. There were no observable significant effects due to banking. The extremely low mean grain yields without banking shown in Table 11 come from *dambo* plots in Chiradzulu where farmers either banked all the plots or did not bank any of them. Three of the farmers who did not bank any of the research plots in their field had extremely low maize yields of less than 200 kg/ha. The difference between banking and not banking could not be assessed even for this group of farmers because banking or not banking did not happen within farms, only between farms.

Finally investigated were the effects of *mbwera* in Matapwata EPA. There was insufficient evidence in the data to demonstrate that *mbwera* had any effect on maize yield parameters (Table 14).

Table 12. Mean yield values and significance of effects in farm-level analysis

		Average over plots with no seed dressing		Average over seed-dressed plots	
Parameter	**Location**	***Dambo***	**Upland**	***Dambo***	**Upland**
Mean grain yield (kg/ha)	Chiradzulu	1125	2913	1409	3684
	Matapwata	1316	1986	1262	2623
Mean height (m)	Chiradzulu	1.72	2.21	1.73	2.39
	Matapwata	1.71	1.84	1.73	1.94
Average weight/cob (kg)	Chiradzulu	0.080	0.165	0.087	0.184
	Matapwata	0.117	0.144	0.105	0.147
Number of cobs/plant	Chiradzulu	0.716	0.968	0.703	0.985
	Matapwata	0.848	0.908	0.872	0.981

Table 13. Mean yields to show beneficial effects of seed dressing

Yield response	With seed dressing	Without dressing	Difference in means	SE (diff)	*P*
Mean grain yield (kg/ha)*					
Dambo	1312	1193	119	104.3	0.255
Upland	2721	2216	505	103.7	<0.001
Mean height (m)	1.891	1.840	0.0515	0.0209	0.015
Average weight of cobs (kg)	0.121	0.119	0.0017	0.0028	0.550
No. cobs/plant	0.852	0.843	0.0089	0.0155	0.568

*Only mean grain yields have been disaggregated by zone since this was the only response variate which gave a significant zone by seed dressing interaction.

Table 14. Results on the use of *mbwera* in Matapwata EPA

Yield response	Use of *mbwera* (mean values)		*P*
	With	Without	
Mean grain yield (kg/ha)	1564	1784	0.098
Mean height (m)	1.870	1.861	0.756
Average weight of cobs	0.130	0.134	0.392
No. cobs/ plant	0.908	0.949	0.077

Analysis of damage data at harvest

At harvest, data were collected on the numbers of whitegrubs in a random sample of five plants. Frequency distributions for these numbers over the 244 plots in the trial are shown in Table 15. A skewed distributional pattern is seen. There are also a large number of plots showing no incidence of whitegrub attack.

Whitegrub numbers at harvest

The effects of seed dressing and banking on whitegrub numbers were investigated using a generalized linear model with Poisson distributed errors. For whitegrub numbers, there was some evidence of a difference between the EPAs (P=0.029) and strong evidence of a difference between *dambo* and upland areas (P<0.001). The application of seed dressing also had a beneficial effect (P<0.001) but there was no evidence of an effect due to banking (P=0.576). Further investigation of the seed dressing effect showed an interaction with the land type (P=0.009). The effect of seed dressing appeared to be evident only in *dambo* areas and not in the uplands. The mean numbers of whitegrubs/plot are shown in Tables 16 and 17.

Table 15. Frequency distribution for numbers of whitegrubs

Whitegrubs*	Plots
0	93
1	52
2	44
3	19
4	17
5	9
6–10	8
11–15	2
Total	244

*Numbers of whitegrubs found in five plants.

Whitegrub incidence during the season

Mean numbers of plants/plot, dead or attacked by whitegrubs, were studied at each sampling occasion for plots with/without seed dressing. There was little incidence during the season but where it occurred, yields were about 8–10 t lower in plots with seed dressing than for plots without seed dressing. Deaths due to larval whitegrub were found mainly in the first two sampling occasions (10 December–2 January 1998). Deaths caused by adult beetles were noted only at the seventh sampling occasion (9–14 March 1998). There was little indication that banking had an effect on mean numbers of plants/plot affected by whitegrub.

The actual numbers of plots affected over the entire season by whitegrub and hence, giving rise to varying numbers of affected plants, are shown in Table 18. The percentage of plots affected was about 30%.

Chi-square tests were applied to determine whether the proportion of plots affected by whitegrub attack differed significantly across the seed dressing and banking treatment effects. The results are shown in Tables 19 and 20 for plots with dead plants due to whitegrubs and plots attacked by whitegrubs. The results indicate a significant lowering of

Table 16. Mean whitegrub numbers/plot at harvest by zone and seed dressing factors

Seed dressing	*Dambo*	Upland
No	2.71	3.77
Yes	1.54	3.68
P	<0.001	0.879

Table 17. Mean whitegrub numbers/ha at harvest in different EPAs, zones and across treatment factors

EPA, zone and treatment factor		Sample size	Mean whitegrub numbers/ha	*P*
EPA	Chiradzulu	136	4.95	0.029
	Matapwata	108	0.90	
Zone	*Dambo*	120	2.13	<0.001
	Upland	124	3.72	
Seed dressing	No	122	3.24	<0.001
	Yes	122	2.61	
Banking	No	64	2.68	0.576
	Yes	180	2.96	

Table 18. Number of plots affected by whitegrubs (*n*=244)

No. plants affected/plot	Dead plants caused by whitegrub larvae	Dead plants caused by whitegrub adults	Attacked by whitegrub
0	225	240	192
1–4	8	2	31
5–10	8	0	16
>11–15	3	0	5
No. plots affected	19	4	52
% plots affected	7.8%	1.6%	21.3%

Table 19. Number and percentage of plots with dead plants due to whitegrubs

Effect of whitegrub	Seed dressing		Banking	
	No	Yes	No	Yes
No dead plants	102 (83.6%)	119 (97.5%)	55 (85.9%)	166 (92.2%)
Dead plants	20 (16.4%)	3 (2.5%)	9 (14.1%)	14 (7.8%)
P	<0.001		0.139	

Table 20. Number (and percentage) of plots with plants attacked by whitegrubs

Effect of whitegrub	Seed dressing		Banking	
	No	Yes	No	Yes
No dead plants	89 (73%)	103 (84.4%)	55 (85.9%)	137 (76.1%)
Dead plants	33 (27%)	19 (15.6%)	9 (14.1%)	43 (23.9%)
P	0.029		0.099	

Table 21. Whitegrub incidence at plot/plant level over sampling occasions

	Incidence at plot level (*n*=24)	Incidence at plant level (*n*=12 834–25 542)
Sampling occasion	% of plots showing incidence	% of plants killed by larvae/adults
11/12/97–17/12/97	6.1	0.33
29/12/97–2/1/98	2.0	0.14
12/1/98–16/1/98	0.4	0.01
26/1/98–1/2/98	0	0
13/2/98–25/2/98	0	0
26/2/98–5/3/98	0	0
9/3/98–14/3/98	1.6	0.21
23/3/98–31/3/98	0	0

Table 22. Number (and percentage) of plants killed by whitegrubs, totalled over all sampling occasions

	Chiradzulu		Matapwata		
Seed dressing	***Dambo***	**Upland**	***Dambo***	**Upland**	**Totals**
Without dressing	0.59%	1.85%	0.97%	1.57%	0.13%
With dressing	0%	0.13%	0%	0.21%	0.09%
Totals	0.28%	0.97%	0.46%	0.84%	0.65%
	19	72	27	52	170
n	6827	7387	5817	6164	26195

Table 23. Number (and percentage) of farmers experiencing whitegrub attack on research plots

	No. plots affected					
Farmers	**0**	**1**	**2**	**3**	**4**	**Total**
Number	47	8	4	1	1	61
Percentage	77.0	13.1	6.6	1.6	1.6	100

whitegrub incidence in plots with seed dressing compared to plots without seed dressing. There was insufficient evidence to demonstrate an effect due to banking.

Incidence of plant deaths due to whitegrubs at plot (and plant) level over the eight sampling occasions is shown in Table 21. The plot level summaries show that less than 10% of plots are affected, while the plant level summaries show that the proportion of plants killed by whitegrubs (in approximately 2-week periods) is less than 0.5%. Incidence is greater in the early part of the season.

The numbers of plants killed by whitegrubs, totalled over all sampling occasions, are shown in Table 22. The percentages shown correspond to the numbers killed as a proportion of the initial germination stand count. The latter has been taken as the maximum number of standing (live) and dead plants over the first two sampling occasions. The overall incidence of plants killed by whitegrubs is low (less than 2%), but there does appear to be a reduction in incidence for plots that have maize seed dressing. Incidence in Matapwata is substantially higher than in Chiradzulu within *dambo* areas but there appears to be little difference in the uplands.

It was also interesting to see how many farmers had 0, 1, 2, 3 or 4 of the research plots on their farm with plants killed by whitegrubs. The results in Table 23 show that most farmers (77%) had no plants killed by whitegrubs. Only six farmers (about 10%) had whitegrub incidence in more than one of their plots.

The results presented so far in this section all relate to raw data summaries. Data on the numbers of plants killed by whitegrub larvae or adults, considered as a proportion of the initial plant stand, were subjected to a generalized linear modelling procedure to investigate whether this proportion was affected by seed dressing, having allowed for possible effects due to variation between EPAs, zones and farmers. Predictions following the modelling procedures are shown in Tables 24 and 25. There was no evidence of an EPA effect ($P=0.825$). Seed dressing significantly reduced plant proportions killed by whitegrub ($P<0.001$). *Dambo* areas had a significantly lower incidence than the uplands. There was also a significant zone by seed dressing interaction ($P=0.006$).

There was evidence of an effect due to banking ($P=0.010$) and a banking by zone interaction ($P<0.001$). Banking appears to slightly reduce the percentage of plant deaths due to whitegrubs. The overall incidence, however, is very low.

It is important to note that the occurrence of highly significant differences is not an indication that the results are of practical significance. The overall incidence is extremely

Table 24. Model predictions of percentage of whitegrub-affected plants across seed dressing levels

	Zone		
Seed dressing	***Dambo***	**Upland**	**Overall seed dressing effect**
No	0.77	1.73	1.26
Yes	0	0.17	0.09
Overall zone effects	0.36	0.91	*P* for difference between seed dressing levels is <0.001

P for difference between *dambo* and upland areas is <0.001

Table 25. Model predictions of percentage of whitegrub-affected plants across banking levels

	Zone		
Banking	***Dambo***	**Upland**	**Overall banking effect**
No	0.40	1.20	1.26
Yes	0.35	0.80	0.09
Overall zone effects	0.36	0.91	*P* for difference between banking levels is 0.010

P for difference between *dambo* and upland areas is <0.001

low and it is clear that most farmers do not have serious problems with whitegrub attacks on maize. Demonstrating that a very minor attack with no seed dressing is significantly reduced by the application of seed dressing is of no practical value. Therefore not too much emphasis should be placed on the significant findings reported above.

Conclusions from the 1997/98 trial

The main finding is a clear beneficial effect of the application of seed dressing with Gaucho in upland areas. The increase in usable grain weight (kg/ha) with seed dressing was about 500 kg/ha (SE = 104) in the upland areas, but only about 120 kg/ha (SE = 104) in *dambo* areas. Seed dressing had only a marginal effect on the mean height of plants (P=0.015). There was no evidence of an effect of seed dressing on the average weight of a cob, nor on the number of cobs/plant.

The mean number of whitegrubs found at harvest time on a random sample of five plants differed significantly across EPAs (P=0.029), zones (P<0.001) and seed dressing levels (P<0.001). A lower incidence was found in Matapwata, in *dambo* areas and in plots which had been seed dressed. There was insufficient evidence of an effect due to banking.

During the season, no record was made of whitegrub numbers, only the number of plants affected in each plot. Incidence in terms of plots with dead plants was low (less than 10%). However, about 20% of plots showed plants attacked by whitegrub. Less than 0.5% of plots were found to have more than 10 plants killed or attacked by whitegrub during the season.

The percentage of plots affected by whitegrubs differed significantly between plots with and without seed dressing. The incidence in terms of dead plants was about 16% for plots with no seed dressing compared to about 3% for plots with seed dressing. Attack by whitegrubs was also significantly lower (about 16%) for seed-dressed plots compared to plots without seed dressing (27%). There was no evidence of an effect due to banking.

WHITEGRUB MANAGEMENT TRIAL 1998/99

During the 1998/99 cropping season, *Tephrosia* and seed dressing with Gaucho-T 45 WS were tested for the management of whitegrubs. The FSIPM Project has been using the legume, *Tephrosia vogelii* (fish bean) as a green manure to improve soil nutrient status and organic matter content. *T. vogelii* contains rotenoids and tephrosin which have insecticidal activity. Although results from the 1997/98 on-farm trials by the project showed that Gaucho 70 WS significantly reduced the number of plants killed by whitegrubs (Abeyaskera, 1999), the cost (US$ 41.50/125 g packet) is prohibitive for application by the smallholder farmer. Therefore, a cheaper formulation combining Gaucho 70 WS and thiram, called Gaucho-T (35% Gaucho: 10% thiram) was selected for the 1998/99 trial. The aim of the trial was, therefore, to assess the effect of incorporating *Tephrosia* leaves at 2 t/ha wet biomass and Gaucho-T on whitegrub numbers, plant deaths due to whitegrubs and maize yield.

Design of the 1998/99 trial

In the 1998/99 season, a smaller trial involving just nine farmers was conducted; these farmers were those who had experienced high whitegrub populations in previous years. The four plots used in the 1997/98 trial (two with Gaucho seed dressing, two without) were split in half to give eight plots, each 5.4 x 5.4 m. The treatment combinations were:

1. Gaucho in 1997/98, no Gaucho in 1998/99, no *Tephrosia* incorporated

Table 26. Mean yield responses by location and for seed dressing treatments

Yield response	Seed dressing	Chiradzulu *Dambo*	Chiradzulu Upland	Matapwata Upland
Usable grain weight	No	1398	2947	1106
	Yes	1468	3376	1105
Average weight/cob	No	0.107	0.120	0.076
	Yes	0.103	0.202	0.083

Table 27. Mean yield responses by location and incorporation or not of *Tephrosia*

Yield response	*Tephrosia* incorporated	Chiradzulu *Dambo*	Chiradzulu Upland	Matapwata Upland
Usable grain weight	No	1328	2959	1073
	Yes	1538	3363	1137
Average weight/cob	No	0.099	0.188	0.073
	Yes	0.111	0.210	0.087

2. Gaucho in 1997/98, Gaucho in 1998/99, no *Tephrosia* incorporated
3. Gaucho in 1997/98, no Gaucho in 1998/99, *Tephrosia* incorporated
4. Gaucho in 1997/98, Gaucho in 1998/99, *Tephrosia* incorporated
5. no Gaucho in 1997/98, no Gaucho in 1998/99, no *Tephrosia* incorporated
6. no Gaucho in 1997/98, Gaucho in 1998/99, no *Tephrosia* incorporated
7. no Gaucho in 1997/98, no Gaucho in 1998/99, *Tephrosia* incorporated
8. no Gaucho in 1997/98, Gaucho in 1998/99, *Tephrosia* incorporated

The above treatment structure falls into a 2 x 2 x 2 factorial array. As in 1997/98, maize was intercropped with bean and pigeonpea. Maize and pigeonpea were planted at a rate of 3 seeds/station, beans at 2 seeds/station. Damage assessments were made at each of eight sampling occasions.

Maize harvest data – basic summaries

Two yield responses were considered for analysis:

- usable grain weight (kg/ha) adjusted for stolen cobs and moisture content
- average weight/cob (kg), i.e. ratio of the weight of all cobs at harvest to the number of cobs.

Mean values for each of these responses by location and the 1998/99 *Tephrosia* and seed dressing treatments are shown in Tables 26 and 27.

Modelling maize harvest data

The 1998/99 whitegrub trial had data arising from three different types of fields and locations, i.e. Chiradzulu *dambo*,

Table 28. Mean usable grain weight (kg/ha) across seed dressing

Treatment factor	Chiradzulu		Matapwata
	Dambo	Upland	Upland
No seed dressing	1396	2926	1104
Seed dressing with Gaucho	1466	3454	1103
Diff. in means	70	528	–1
SE (diff)	232	168	190
P	0.763	0.003	0.991

Table 29. Mean usable grain weight (kg/ha) according to *Tephrosia* incorporation

Treatment factor	Chiradzulu		Matapwata
	Dambo	Upland	Upland
No *Tephrosia*	1327	2937	1073
Tephrosia incorporated	1538	3448	1137
Diff. in means	211	511	64
SE (diff)	230	166	188
P	0.365	0.003	0.735

Table 30. Mean numbers of whitegrubs when *Tephrosia* incorporated

Sampling occasion	Size (cm)	*Tephrosia* Not incorporated	*Tephrosia* Incorporated	*P*
1	0–15	20.0 ±5.93	49.0 ± 9.20	***
	15–30[1]	–	–	–
2	0–15	20.0 ±4.19	19.0± 4.09	NS
	15–30	37.0 ±5.51	69.0 ± 7.22	*

[1]Sampling was not carried out during first sampling occasion.
Significance: *, significant at 5%; ***, significant at 0.1%; NS, not significant.

Chiradzulu upland and Matapwata upland. The analysis involved fitting analysis of variance models to the yield responses, allowing for variation across types of fields and locations, residual farm-to-farm variation, treatment factors and their interaction with type of field and location.

Usable grain weight (kg/ha)

Overall effects of seed dressing and *Tephrosia*, averaged over land types and EPAs, were found to be significant (P=0.030 for seed dressing and P=0.013 for *Tephrosia*). However, further analysis showed that a significant beneficial effect was evident only in the Chiradzulu uplands. Tables 28 and 29 summarize the results.

Average weight per cob (kg)

Only *Tephrosia* incorporation was found to have an effect on the average weight of cobs (P=0.003). However, the increase in cob weight was quite marginal, increasing merely from 139 g to 157 g (SE (diff)= 0.006).

Effect of *Tephrosia* on whitegrub numbers

Table 30 shows the mean numbers of whitegrubs as affected by the incorporation of *Tephrosia* at two sampling occasions. *Tephrosia* significantly increased whitegrub numbers during the first sampling period (P<0.001) and during the second sampling period at level 2 (P<0.05) compared to the control. However, *Tephrosia* had no significant effect on whitegrub numbers during the second sampling occasion at level 1 (samples from a depth of 0–15 cm). This is contrary to the expected results. Leaves of *Tephrosia vogelii* were expected to reduce whitegrub numbers. It is possible that the botanical insecticides in *Tephrosia* are broken down rapidly after incorporation. Since *Tephrosia* is a green manure, its decomposition could encourage whitegrubs in the soil because of the increased organic matter content.

Conclusions from the 1998/99 trial

Whitegrub management using Gaucho-T and incorporation of Tephrosia vogelii *leaves*

The main finding was that the use of Gaucho-T and *Tephrosia* leaves increased maize yields though the beneficial effect was only realized in upland fields in Chiradzulu (Mombezi EPA).

Neither Gaucho 70 WS nor Gaucho-T are yet approved as seed dressings for maize in Malawi, although Gaucho 70 WS is routinely used for this purpose in South Africa and Kenya. The smallest packet size currently available is 125 g which is too expensive for most smallholder farmers.

The most economical way in which Gaucho can be used is as a treatment for hybrid maize seed by seed companies (as occurs at present with thiram treatment). In the case of composite seed, which is promoted by government and NGOs rather than commercial companies, there appears to be scope for mass treatment of seed before distribution. Compared to most other pesticides Gaucho is of very low toxicity and is very stable during storage. Supplies might be obtained using existing arrangements with donors (e.g. Kennedy Round Funding) (G. Lenoux, personal communication).

Number of whitegrubs

The study found that incorporating *Tephrosia vogelii* leaves in the soil increased the numbers of whitegrubs. Though the incorporation of *T. vogelii* leaves has a beneficial effect in increasing maize yields, there is one major drawback in that it encourages whitegrub populations in the soil. This, however, requires further investigation since the conclusion made is based on 1 year's data and a small number of farmers. Gaucho-T had no significant effect on whitegrub numbers.

ECONOMIC ANALYSIS

An economic analysis was carried out by Mwale (1999).

Table 31 compares the economic returns of seed dressing maize with Gaucho at FSIPM Project research sites in Matapwata and Chiradzulu uplands in 1997/98. Maize yields with seed dressing in Chiradzulu were 2976 kg/ha, and 2472 kg/ha without seed dressing. Adjusted downwards by 20% to allow for farmer management, these were equivalent to 2381 kg/ha and 1978 kg/ha, respectively.

Gross benefits were higher for plots where maize was seed dressed with Gaucho (MK15 477/ha) than where it was not seed dressed (MK12 857/ha). When the cost of Gaucho was included in the variable costs, returns over variable costs (net benefits) were MK9504/ha with seed dressing compared to MK7507/ha without seed dressing. The benefit–cost ratio (full-cost basis) for seed dressing (2.59) was similar to the ratio without seed dressing (2.40), but gross returns to labour were higher for seed dressing (MK67/day) compared to MK52/day without seed dressing. The marginal rate of return, which is the marginal net benefit divided by the marginal cost (320%) indicates that farmers can expect to gain, on average, in return for their investment when they decide to seed dress their maize seed with Gaucho.

In Matapwata, maize yields in the 1997/98 season were slightly lower than in Chiradzulu. Average maize yield was 2465 kg/ha with seed dressing, and 1960 kg/ha without seed dressing. Adjusted downwards by 20% to allow for farmer management, these were equivalent to 1972 kg/ha and 1568 kg/ha, respectively.

As in Chiradzulu, gross benefits were also higher for plots with seed dressing (MK12 818/ha) than without seed dressing (MK10 192/ha). When the cost of Gaucho was included in the variable costs, net benefits were MK6845/ha and MK 4842/ha, respectively. The benefit–cost ratio (full-cost basis) for seed dressing was higher with seed dressing (2.15) than without seed dressing (1.91). Overall gross returns to labour were also high for seed dressing. The marginal rate of return for Matapwata was 321%, also indicating that farmers can expect to gain in return for their investment when they decide to seed dress with Gaucho.

Table 31. Economic evaluation of Gaucho for treatment against whitegrubs 1997/98

Variable	Chiradzulu upland: Without seed dressing	Chiradzulu upland: With seed dressing	Matapwata upland: Without seed dressing	Matapwata upland: With seed dressing
Benefits				
Yield (kg/ha)	2472	2976	1960	2465
Adjusted yield (kg/ha)	1978	2381	1568	1972
Unit price	6.50	6.50	6.50	6.50
Gross benefits	12 857	15 477	10 192	12 818
Variable costs				
Materials (MK/ha)				
Seed	1000	1000	1000	1000
Fertilizer	890	890	890	890
Credit	202	202	202	202
Other material inputs (Gaucho)	0	623	0	623
Labour requirements (h/ha)	850	850	850	850
Labour for intervention (h/ha)	0	0	0	0
Total labour requirements (h/ha)	850	850	850	850
Unit price (MK/day)	23	23	23	23
Imputed labour cost (MK/ha)	3258	3258	3258	3258
Total costs	**5350**	**5973**	**5350**	**5973**
Net benefits				
Return over variable costs (MK/ha)	7507	9504	4842	6845
Benefit–cost ratio (full-cost basis)	2.40	2.59	1.91	2.15
Benefit–cost ratio (cash-cost basis)	6.15	5.70	4.87	3.57
Gross returns to labour (MK/day)	52.99	67.09	34.18	48.32

Sample size = 61.
Marginal rate of return for applying Gaucho:

Chiradzulu upland
= Marginal benefit/marginal cost
= (9504–7507)/(5973–5350)
= 1997/623
= 3.2054=320.54%

Matapwata upland
= marginal benefit/marginal cost
= (6845–4842)/(5973–5350)
= 2003/623
= 3.2150=321.5%

Table 32 presents the same analysis for Chiradzulu upland only in the 1998/99 season. Matapwata upland fields showed insignificant benefits from Gaucho for the 1998/99 season. Again, the results in Chiradzulu favoured seed dressing against no seed dressing.

Gross benefits with seed dressing were MK23 486/ha compared to MK19 899/ha without seed dressing. Net benefits with seed dressing were MK15 412/ha and MK13 015/ha without seed dressing. The benefit–cost ratios at full cost were similar but returns to labour were higher for seed dressing (MK108/day compared to MK92/day. With a marginal rate of return of 201%, farmers should expect to gain if they seed dress with Gaucho.

CONCLUSION

Economic analysis (Mwale, 1999) shows that farmers could benefit by seed dressing their maize seed with both Gaucho 70 WS and Gaucho-T for the management of whitegrubs. The potential benefits to be realized by farmers are higher in Charadzulu North than Matapwata EPA. The benefits from use of Gaucho are not restricted to whitegrub management but also include reduction in damage by termites as FSIPM Project results indicate (Ritchie *et al.*, p. 77). However, the cost of Gaucho remains the limiting factor for adoption by the smallholder farmer.

Farmer evaluation

For the 1998/99 season, a decision was made to concentrate the trials related to termite and whitegrub on the fields of farmers who had a specific problem in previous years and to omit any treatments related to companion crops (pigeonpea and bean). This enabled farmers to concentrate on the performance of the specific treatments. At the same time a much larger monitoring exercise was mounted to elicit farmer assessment of trial performance during the season. Farmers were also given the opportunity to use seed treatment on their own seed and under their own management. This was successfully implemented and farmers reported that they had no difficulties with the technique. However, as indicated above low incidence and patchy distribution of damage due to whitegrubs remained a problem.

Farmers observed that maize in treated plots had better survival, was more vigorous and healthy, and better yields were expected than from the untreated plots (Kapuplula and Lawson-McDowall, 1999).

Table 32. Economic evaluation of Gaucho for treatment against whitegrubs 1998/99, Chiradzulu upland

Variable	Without seed dressing	With seed dressing
Benefits		
Yield (kg/ha)	2926	3454
Adjusted yield (kg/ha)	2341	2763
Unit price	8.50	8.50
Gross benefits	19899	23486
Variable costs		
Materials (MK/ha)		
Seed	1000	1000
Fertilizer	2140	2140
Credit	486	486
Other material inputs (Gaucho-T)		1190
Labour requirements (h/ha)	850	850
Labour for intervention (h/ha)	0	0
Total labour requirements (h/ha)	850	850
Unit price (MK/day)	23	23
Imputed labour cost (MK/ha)	3258	3258
Total costs	**6884**	**8074**
Net benefits		
Return over variable costs (MK/ha)	13015	15412
Benefit–cost ratio (full-cost basis)	2.892	2.91
Benefit–cost ratio (cash-cost basis)	5.49	4.88
Gross returns to labour (MK/day)	91.87	108.79

Sample size = 9 (Chiradzulu upland only).
Marginal rate of return for applying Gaucho:
=marginal benefit/marginal cost
=(15 412–13 015)/(8074–6884)
=2397/1190
=2.0142=201.42%

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DISCUSSION

F. M. T. Gondwe. Why did the farmer or researcher choose Sevin, Gaucho and *Tephrosia*?

T. D. M. We had been using *Tephrosia* as a green manure to improve soil fertility. As it was known to contain insecticidal compounds, e.g. tephrosin, it was decided to also use it to control whitegrub. Gaucho and Gaucho-T have been recommended for use against whitegrubs in South Africa and Kenya.

A. M. Chirembo. The *Tephrosia* study involved nine farmers. Was the pattern of increase in whitegrub in *Tephrosia* plots the same for all farmers or was it based on the aggregate?

T. D. M. It was based on the aggregate numbers.

C. Pelekani. Since the whitegrub populations vary from year to year, can we identify the factors that determine the numbers and try to manipulate them so that we end up with reduced whitegrub populations?

T. D. M. The major factor is soil moisture content and, therefore, indirectly, rainfall.

B. Kamanga. Did you apply the Gaucho-T at the same time as you incorporated *Tephrosia*?

T. D. M. Tephrosia leaves were incorporated 2 weeks prior to planting while seed dressing with Gaucho was carried out at planting.

V. Kabambe. In some cases it was not economical to apply Gaucho. Is there a way of predicting the levels in order to tell farmers when not to apply?

T. D. M. Currently, there is no information available on economic or action thresholds. However, the presence of the black maize beetle, *Heteronychus* sp. would warrant treatment.

On-farm trials of a farmer-developed cultural pest management strategy for termites in Blantyre/Shire Highlands

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ABSTRACT

This paper reports the results of three seasons of on-farm trials (1996/97 to 1998/99) of candidate cultural pest management strategies against termites attacking smallholder intercropped maize in Blantyre/Shire Highlands. The first pest management strategy for termites was to carry out second weeding without the normal banking up of the ridge, a farmer-developed cultural practice designed to avoid burying rotting organic matter close to the maize roots where it is believed to attract termites. The second strategy was to isolate mature maize plants from the surrounding soil, by removing soil from the old ridges between planting stations in order to form a new ridge in the furrow on which a relay crop of beans was planted (*kaselera*). However the new *kaselera* ridges caused the relay beans to desiccate, reducing yields by an average of 28.7 kg (P=0.05), so this practice was replaced in 1997/98 by a related technique (*mbwera*) in which the soil removed is spread within the furrow to create a flat planting area for the relay bean crop. In 1996/97 each of 32 farmers with upland fields had a single 10.8 x 10.8 m experimental plot with a specific factorial combination of treatments, designed to ensure that all relevant two-factor interactions could be assessed. All pest management strategies were tested within a single trial included within a larger group of 64 farmers. Treatments for maize also included seed dressing with Sevin (carbaryl) against whitegrubs, a practice already adopted by some farmers with *dambo* fields. Though technically efficient this design was confusing for farmers, and was replaced in 1997/98 by four smaller plots in each farm, each with a different treatment combination, the same combinations replicated across 61 farms. The trial did not show any evidence that the cultural practices or the Sevin seed dressing affected levels of termite damage or maize grain yield. However, early second weeding was found to significantly increase maize yield by 387 kg/ha. In 1997/98, treatments for the management of termite damage involved presence or absence of *mbwera* (in Matapwata Extension Planning Area) and second weeding with or without banking (in Chiradzulu North). Seed dressing with Gaucho 70WS (imidacloprid) was used as a management strategy for whitegrubs. Termite attack affected about 40% of plots during the season, mainly towards harvest. 46% of farmers had no termite attack on their plots, but 21% had each of their four plots attacked. The mean percentage of plants attacked never exceeded 3%. There was no evidence that either of these cultural practices affected termite damage or maize yield during the season. However, both no banking and seed dressing had a significant effect in reducing termite lodging of maize at harvest (P=0.001), although the numbers of plants involved were small and significance must be treated with caution. In 1998/99 a group of 12 farmers was selected on the basis of having experienced termite damage in the previous two seasons. Farmers were to compare banking (*kubandira*) against weeding without banking (*kukwezera*), and seed priming against normal planting. In the event there was very little termite attack due to heavy rains, and some farmers varied the weeding treatment to address this. There was no significant beneficial effect of either banking or seed priming on either termite lodging or maize or grain yields. There appeared to be a marginal increase in termite damage to living plants with seed priming. In all 3 years, termite attack was sporadic in time and space and significant treatment effects could be demonstrated only occasionally, despite the shared belief of farmers and researchers that banking does increase termite damage. It is concluded that farmers and extensionists need to be given details of the available range of weeding options from which to choose the most appropriate strategy for a particular situation.

INTRODUCTION

Background

The Farming Systems Integrated Pest Management (FSIPM) Project, financed by the UK Department for Overseas Development and the Government of Malawi, and based within the Department of Agricultural Research and Technical Services at Bvumbwe Research Station, has been conducting on-farm trials and investigations to develop appropriate pest management recommendations for major pests of maize, bean, pigeonpea and sweet potato which can be extended to resource-poor farmers in the Blantyre/Shire Highlands Rural Development Programme area of Blantyre Agricultural Development Division. The initial crop focus of the project was determined by a Stakeholder Workshop in June 1996 which also highlighted particular key pests (Ritchie, 1996). The rationale for selection of specific Extension Planning Areas (EPAs) within the Rural Development Programme area and specific villages within those EPAs has been documented by Ritchie (1997).

Economic importance of termites

The Chancellor College/Natural Resources Institute Soil Pest Project conducted surveys of soil insect pests in farmers' fields in the 1990/91 and 1991/92 seasons. Termites were found to be the major insect pests of maize in all EPAs surveyed (Logan *et al.*, 1995). Most damage took place near to harvesting with a mean of 23.7% of plants attacked, of which 73.5% were severely damaged. During the vegetative stage 12.9% of plants were attacked, and 60.6% were severely damaged. The Maize Productivity Task Force identified termites as the main national priority for pest management.

Several meetings were held with separate groups of men and women farmers in the selected villages to discuss their perceptions of priority pests on their crops and possible control methods. Whitegrubs, termites, cob rot and *Striga asiatica* were perceived by farmers as the most serious field pests of maize. With the exception of cob rot, all field pests were perceived as increasing in severity. Farmers also used a wide range of control methods, several of which (e.g. the use of Sevin seed dressing) were innovative farmer practices. The perceptions of farmers are consistent within and between Matapwata and Chiradzulu, and also show similarity with the views of the group of professionals and experts assembled at the Stakeholder Workshop.

Many farmers believe that the second weeding and re-ridging (*kubandira*) conventionally carried out in maize causes increased termite damage because the decomposing organic material brought into contact with the maize plants attracts termites. A recent survey (Orr *et al.*, 1999) has documented the range of alternative strategies used to reduce this problem without foregoing the benefits of weeding altogether. In Katuli EPA, maize is grown on the previous winter season's bean crop ridges. After several weeks the ridge is partly demolished and dragged into the inter-row to form a new ridge. Later more soil is pulled away from the maize plants to augment the new ridge. This practice, known as the *chisalanga/kaselera* system, was proposed by the Soil Pest Project to reduce lodging due to termite attack. In 1996/97 a trial of this approach was conducted on the upland fields of 32 farmers in four villages in Matapwata and Chiradzulu North EPAs.

MAIZE TERMITE TRIAL 1996/97

Context and objectives

The 1996/97 main intercrop trial was conducted with 64 farmers in four villages in two EPAs. This trial was set within the maize/pigeonpea/bean intercropping system with relay cropping of beans or field peas, which is the commonest cropping system in Blantyre/Shire Highlands. The objectives and design of the experiment have been detailed by Ritchie *et al.* (1997).

In addition to evaluation of several IPM strategies relating to pigeonpea and bean, there were two IPM objectives relating to maize.

- Evaluation of a modified *kaselera* system (in upland fields in Matapwata) and weeding without banking at second weeding (in upland fields in Chiradzulu) to reduce lodging of mature maize by termites. The trial followed up the Soil Pest Project technique of using modified *kaselera* tillage to discourage termites by removing soil from around maize plants and forming a new ridge in the furrow on which a relay crop of beans could be planted.
- Evaluation of seed dressing for reduction of damage to maize by whitegrubs. The quantity used and the method followed as closely as possible the farmers' own practice which they described to us.

The advantages of combining trials of pest management strategies for the different crops within one on-farm experiment are listed by Ritchie *et al.* (1997). These include the fact that the approach mirrors the actual farming system; interactions between different pest management strategies and resource competition can be detected and obviated; logistics are simplified by dealing with a limited area and farmer group; a factorial design cuts replication and reduces plot numbers and associated labour and expense.

To gain more detailed information about the performance of maize varieties in relation to termites and whitegrubs, a replicated on-station monocropped varietal maize trial was mounted at the Veterinary Research Station at Thuchila. The results from this trial were analysed and reported by Abeyasekera (1998), and relevant conclusions are reported below in relation to the performance of maize in the main on-farm intercrop trial.

Treatments and experimental design of 1996/97 trial

The maize treatment factor for termites (upland only) was as follows:

- Chiradzulu only – no relay bean crop

1. Hand weed without banking maize at second weeding
2. Control: weed and bank normally at second weeding

- Matapwata only – followed by relay bean crop

1. Use modified *kaselera* system: hand weed without banking at second weeding around time of cob formation (February), leave weeds to dry in furrow, form new ridge (February/March), plant short-duration beans on new ridge.
2. Control: weed and bank at second weeding. Break down ridge to form flat area for beans when maize is drying (February/March), plant short-duration beans on new ridge.

These treatments were a subset of a range of pest management strategies that were carried out for the overall intercrop farming system. During 1996/97, the main trial within a maize/pigeonpea/bean intercropping system involved 64 farmers, with one plot in each farm under an intervention treatment and a second plot being managed by the farmer according to his/her own practice. In view of the trial objectives requiring investigation of two treatment factors for maize (one at two levels, one at three levels), two for pigeonpeas (each at two levels), and five for beans (each at two levels), a very large number of treatment combinations resulted. The experiment was designed to ensure that any 'economic' type of response made in the overall system could be analysed to take account of the full range of strategies tested within the experiment. The design was therefore set up as an incomplete factorial design with a fractional replicate of a 2^8 factorial experiment in four blocks, each having 16 plots, i.e. 64 experimental plots in total, one per farmer being used as the experimental units.

The 1996/97 design as originally proposed, together with a list of the full range of treatment factors used in the trial, are detailed by Abeyasekera (1998).

In addition to the 64 research plots, each farmer had a 'farmer's plot' in the same field where they implemented their own management practices using their own inputs. During the trial, variation in maize height and yields in research plots were found to be closely correlated with variation in the adjoining farmer's plot. This meant that farmers' plot data could be used as a covariate in the analysis which served to account for some inter-farm variation and reduced the residual variance.

Results and conclusions on management of termite damage to maize from 1996/97 trials

Preliminary results were presented to the 1996/97 Annual DAR research meetings (Ritchie *et al.*, 1997) and detailed biometric analyses of all trials have been presented by Abeyasekera (1998). The main conclusions from these analyses are summarized here. It should be noted that all plots were unfertilized, which mirrored the state of many of the surrounding farmers' fields. This probably influenced farmers' weeding decisions and may have altered the performance of and interactions between intercrops.

In general, on-farm termite attack was very low, possibly as a result of the heavy rainfall in the 1996/97 cropping season, although occasionally banked fields were heavily attacked. As a result, there was no evidence for either improved maize yield or reduced termite damage with either *kaselera* or weeding without banking. Modified *kaselera* was found to differ little in reality from the local practice of *mbwera* which is normally undertaken slightly later when maize plants are starting to dry out. *Mbwera* produces a flat planting area which is also used to support a relay crop of beans planted in a regular spacing at high densities, whereas in *kaselera* a new ridge is formed in the inter-row on which beans are planted. In addition the trial showed that the seed yield from relay beans planted on the new *kaselera* ridge was on average 28.7 kg/ha less than those planted on the flat (P=0.051). In a major bean-growing area this would seem to militate against the technique.

An interesting discovery was that, although second weeding without banking and second weeding with banking were indistinguishable in their effect on maize yields and termite attack, there was a marked beneficial effect of early completion of second weeding (by early February) in increasing maize grain yield by 387.4 kg/ha (P=0.027).

The on-station monocropped maize variety trial set up in the hotter and drier area of Thuchila in 1996/97 was designed to detect inter-varietal variation in susceptibility to termite and whitegrub attack. The trial results showed more marked damage to maize than the on-farm intercrop trials in Chiradzulu and Matapwata. Khonga (1997) found that intercropping with pigeonpea significantly reduced termite attack compared to monocropped maize. However, the Thuchila trial showed no significant varietal advantages with respect to termite damage, and consequently varietal testing was discontinued.

MAIZE TERMITE TRIAL 1997/98

Treatment factors and design layout

Maize IPM trials in the 1997/98 season were a follow-up to trials conducted in the 1996/97 season on 61 farms in four villages in Chiradzulu and Matapwata EPAs. The more expensive but less toxic alternative seed dressing, Gaucho 70WS (imidacloprid), which is sold elsewhere in Africa specifically for whitegrub control, was used instead of Sevin. The experiment was conducted both in *dambo* fields (as for 1996/97) and in upland fields, because it had been established in 1996/97 that larval whitegrub attack occurs throughout the area and also because there is known to be an anti-feedant effect of Gaucho on termites which it was hoped would be detectable on upland farmers' trial plots.

Farmer evaluation of IPM strategies carried out by Jere (1997) using semi-structured interviews was hampered by the complex experimental design and by the fact that each farmer saw only one treatment combination and, therefore, could not observe the full range of treatments on their fields. In some cases farmers were unsure of the intended effect of a strategy. The design of experiments for the 1997/98 season was specifically intended to ensure that most of the proposed combinations of management practices would be visible to each farmer on one or more of the four experimental plots on his or her farm. In addition, there was a radical reduction in the number of treatment combinations involved (two factors for maize, one for pigeonpea and one for bean) focusing attention on those interventions most likely to have a significant effect which could be evaluated by farmers.

The two treatment factors for maize were:

- seed dressing with Gaucho for the management of whitegrubs;
- *mbwera* plus weeding without banking, or no *mbwera* and normal banking in Matapwata and weeding with or without banking (in Chiradzulu North) for the control of termites.

On beans and pigeonpeas, only varietal tolerance was investigated. In both cases four varieties were used, including a local check. The yield and damage responses for these intercrops were analysed separately and are not considered further here. There were no significant interactions between maize treatments and intercrop varieties present on the plots.

Table 1. Distribution of farmers across villages and land types (1997/98)

Land type (zone)	Chiradzulu		Matapwata		
	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	11	6	8	5	30
Upland	5	12	7	7	31
Total	16	18	15	12	61

The general form of the experimental design used for the 1997/98 main intercrop trial was that of a randomized block experiment with a factorial treatment structure, with four units per farm forming a block. Factorial combinations between treatment factors were allocated to the incomplete blocks so that all important two-factor interactions could be estimated. The design layout (unrandomized) for farms in each village and by zone (*dambo*/upland) is described by Abeyasekera (p. 28).

A total of 61 farmers participated in the 1997/98 main intercrop trial, each farmer maintaining four research plots on one of his/her fields. The distribution of farmers across villages is shown in Table 1 according to the type of land (*dambo*/upland) farmed. The land type will be referred to as the 'zone' in what follows. In each farm two plots had maize seed dressing and two did not. Where banking and *mbwera* were applied, two plots were banked, two were left unbanked, *mbwera* was done on two of the four plots.

Maize harvest data basic summaries

Four yield responses were considered for analysis. These were:

- usable grain weight (kg/ha) adjusted for stolen cobs and moisture content;
- mean height of 10 randomly selected plants from the net plot at harvest (m);
- average weight per cob (kg), i.e. ratio of the weight of all cobs at harvest to the number of cobs;
- average number of cobs per plant = number of cobs per net plot stand count.

Basic summary statistics for these responses by zone, and the means under each of the treatment factors across zones, are shown in Tables 2 and 3. Table 2 shows that the maize yield performance is generally better in upland fields than in *dambo* fields. Results in Table 3 demonstrate a beneficial effect due to seed dressing in upland fields with respect to usable grain weight and an improvement in grain yields with banking in *dambo* fields. *Mbwera* appears to have little effect, except for a possibly poor effect in the *dambo* zone.

It is important to note that the summary data presented above make no allowances for other sources of variation that reside in the data, such as the farmer-to-farmer variability, variation due to zones and EPA, etc. Investigation of the effect of the intervention treatments must take these sources of variability into account in order to provide information about the true performance of the maize crop under the different treatments.

Statistical analysis of harvest data

Treatment factors applied at the plot level were investigated. These were the application of seed dressing, banking and the use of *mbwera*. The interactions of these factors with zone and EPA differences were also investigated. *Mbwera* was relevant only within Matapwata, and so the analysis involving *mbwera* was restricted to those farmers in the Matapwata EPA. Banking was generally always practised in Chiradzulu *dambo* areas, so again the analysis involving banking was restricted to the remaining areas.

In the analysis, clear differences were found in maize grain yield between plots which had had seed dressing and those that had not ($P<0.001$). This difference, favouring plots with seed dressing, was mainly due to the substantially greater yields (by about 500 kg/ha) in the upland areas compared to the *dambo* areas (Table 4). The increase in maize yields

Table 2. Summary plot level statistics for four maize yield parameters (1997/98)

Yield response	Zone	No. observations	Mean	SD	Max.	Min.
Usable grain weight (kg/ha)	*Dambo*	118	1239	906	4374	17
	Upland	120	2442	1072	5596	305
Mean height of plants at harvest	*Dambo*	120	1.73	0.291	2.44	1.12
	Upland	124	1.99	0.299	2.86	1.37
Average weight per cob	*Dambo*	120	0.094	0.044	0.209	0.008
	Upland	120	0.142	0.040	0.228	0.062
Average number of cobs per plant	*Dambo*	120	0.753	0.253	1.195	0.060
	Upland	124	0.932	0.137	1.426	0.494

Table 3. Mean values for four maize yield parameters according to land type and treatment factors (1997/98)

Treatment factor		*N*	Usable grain weight (kg/ha)		Mean height of plants at harvest (m)		Average weight/cob (kg)		Average number cobs/plant	
			Dambo	Upland	*Dambo*	Upland	*Dambo*	Upland	*Dambo*	Upland
Seed dressing	Yes	120	1299	2701	1.74	2.03	0.093	0.145	0.755	0.939
	No	118	1180	2174	1.72	1.96	0.095	0.138	0.752	0.925
Banking	Yes	175	1429	2404	1.79	2.01	0.105	0.142	0.827	0.928
	No	63	630	2532	1.53	1.97	0.060	0.141	0.522	0.942
Mbwera	Yes	54	1309	2109	1.74	1.87	0.112	0.138	0.896	0.923
	No	54	1522	2243	1.75	1.83	0.121	0.140	0.927	0.946

Table 4. Mean yields to show beneficial effects of seed dressing (1997/98)

Yield response	With dressing	Without dressing	Difference in means	SED	*P*
Mean grain yields (kg/ha)*					
Dambo	1312	1193	119	104.3	0.255
Upland	2721	2216	505	103.7	<0.001
Mean height (m)	1.891	1.840	0.0515	0.0209	0.015
Av. weight of cobs (kg)	0.121	0.119	0.0017	0.0028	0.550
No. cobs/plant	0.852	0.843	0.0089	0.0155	0.568

*Only mean grain yields have been disaggregated by zone since this was the only response variate which gave a significant zone by seed dressing interaction.

under seed dressing in the *dambo* areas was only about 100 kg/ha. The latter was not a significant difference. There were no observable significant effects due to banking.

The extremely low mean grain yields without banking shown in Table 3 come from *dambo* plots in Chiradzulu where farmers either banked all plots or did not bank any of the plots. Three of those farmers who did not bank any of the research plots in their field had extremely low maize yields of less than 200 kg/ha. The difference between banking and not banking could not be assessed even for this group of farmers, because banking or not banking did not happen within farms, only between farms.

Finally we investigated the effects of *mbwera* in Matapwata EPA. There was insufficient evidence in the data to demonstrate that *mbwera* had any effect on maize yield parameters. The results are summarized in Table 5.

Table 5. Results concerning the use of mbwera in Matapwata EPA (1997/98)

Yield response	Mean values according to use of *mbwera*		
	With	Without	*P*
Mean grain yields (kg/ha)	1564	1784	0.098
Mean height (m)	1.870	1.861	0.756
Av. weight of cobs	0.130	0.134	0.392
No. cobs/plant	0.908	0.949	0.077

Analysis of termite-lodged plants at harvest

At harvest time, data were collected on the number of termite-lodged plants per net plot. Table 6 shows the frequency distribution of numbers of termite-lodged plants over the 244 plots in the trial split between *dambo* and upland areas. Very skewed distributional patterns are seen, and there are also a large number of plots showing no incidence of termite attack. Termite-lodged plants occurred mostly in the upland areas. Only about 17% of plots in the *dambo* areas were affected by termites.

An analysis of the number of termite-lodged plants using a generalized linear model with Poisson errors showed strong evidence of differences between farms with respect to the

Table 6. Frequency distribution of termite-lodged maize plants by zone (1997/98)

No. plants affected/plot	*Dambo*	Upland
0	100	55
1	7	7
2	6	5
3	3	9
4	1	1
5	2	4
6–10	1	21
11–15	8	8
>15	0	14
No. plots	120	124

Table 7. Mean number of termite-lodged plants per net plot of 32.4 m^2 (1997/98)

Seed dressing	Banking (*n*) No	Banking (*n*) Yes	Overall seed dressing effect
No	3.02 (28)	5.35 (94)	4.18
Yes	2.18 (36)	2.30 (86)	2.24
Overall banking effects	2.60 (64)	3.82 (180)	For difference of 1.94 between seed dressing levels $P<0.001$
For difference of 1.22 between banking levels $P<0.001$			

mean numbers of termite-lodged plants and strong evidence of an effect due to the seed dressing factor ($P<0.001$) and due to banking ($P<0.001$). There was also some evidence of a seed dressing by banking interaction ($P=0.016$). As expected, farmer differences were also highly significant. The strong farmer-to-farmer effect was largely caused by four farmers having considerably larger numbers of termite-lodged plants, averaging over 20 lodged plants per plot. The effects of seed dressing and banking are shown in Table 7.

Analysis of termite damage data during the season

Data on the number of maize plants dead, or attacked by, a range of pests/diseases were recorded during the period from early December 1997 to late March 1998 on eight sampling occasions, approximately 2 weeks apart. In Matapwata EPA, data had been collected over only seven sampling occasions. The net plot germination stand count was taken as the maximum of the stand counts and dead plants recorded on the first two sampling occasions. There was little evidence that germination rates differ across villages or zones.

Table 8. Mean number of termite-lodged plants per plot, over sampling occasions and across treatment factors (1997/98)

Sampling occasion	Seed dressing No	Seed dressing Yes	Banking No	Banking Yes
10–18 Dec 1997	0.016	0	0.031	0
28 Dec 97–2 Jan 98	0	0	0	0
12–16 Jan 1998	0	0	0	0
26 Jan–1 Feb 1998	0.033	0.033	0.031	0.033
13–25 Feb 1998	0.492	0.230	0.234	0.406
24 Feb–5 Mar 1998	0.689	0.590	0.641	0.639
9–14 March 1998	0.680	0.713	0.469	0.778
23–31 March 1998	0.868	0.647	0.846	0.722
Totals	0.317	0.255	0.253	0.298

Table 9. Number (and percentage) of plots with termite-lodged plants across treatment factors (1997/98)

Plots with termite-lodged plants	Seed dressing No	Seed dressing Yes	Banking No	Banking Yes
No	74 (60.7)	77 (63.1)	36 (56.3)	115 (63.9)
Yes	48 (39.3)	45 (36.9)	28 (43.8)	65 (36.1)
P	0.693		0.280	

Table 10. Number (and percentage) of farmers experiencing termite attack on research plots (1997/98)

Farmers	No. plots affected 0	1	2	3	4	Total
No.	28	6	7	7	13	61
Percentage	45.9	9.8	11.5	11.5	21.3	100

Mean numbers of termite-lodged plants on each sampling occasion and by seed dressing and banking treatment effects are shown in Table 8. Incidence is very low earlier in the season, but rises slightly later in the season. Neither seed dressing nor banking appears to have an effect. Chi-square analyses to compare proportions of plots with termite-lodged plants across seed dressing and banking treatment factors showed no evidence of a difference. The results are summarized in Table 9.

Looking at the number of farmers who had between none and four of the research plots on their farm affected by termite-lodged plants, the results in Table 10 show that slightly less than half the farmers (46%) had no plants affected by termite lodging in any of the four research plots on their farm. The incidence at plot level was rather high for about 20% of the farmers. These farmers had all four of their plots affected.

Tables in this section have thus far referred to raw data summaries. Data on the numbers of plants with termite lodging, considered as a proportion of the initial plant stand, was subjected to a generalized linear modelling procedure to investigate whether this proportion was affected by seed dressing and by banking, having allowed for possible effects due to variation between EPAs, zones and farmers. Predictions following the modelling procedures are shown in Tables 11 and 12. There was no evidence of an effect due to banking ($P=0.171$). Seed dressing significantly reduced plant proportions with termite lodging ($P<0.001$). There was some evidence of a significant zone by seed dressing interaction ($P=0.044$), and of an EPA by zone interaction ($P<0.001$).

Conclusions from the 1997/98 trial

Termite attack was seen in about 40% of plots during the season. The incidence was higher later in the season than earlier. The severity of attack in terms of the number of plants lodged was very low (2.5% accumulated over the season). Neither seed dressing nor banking affected termite lodging of plants during the season. It is likely that the heavy rains in

Table 11. Model predictions for percentage of termite-lodged plants across seed dressing levels (1997/98)

Seed dressing	Zone: *Dambo*	Zone: Upland	Overall seed dressing effect
No	1.56	3.05	2.33
Yes	0.83	2.55	1.72
Overall zone effects	1.18	2.79	For difference between seed dressing levels $P<0.001$
For difference between *dambo* and upland areas $P<0.001$			

Table 12. Model predictions for percentage of termite-lodged plants across EPAs (1997/98)

EPA	Zone: *Dambo*	Zone: Upland	Overall seed dressing effect
Chiradzulu	0	2.59	1.34
Matapwata	2.56	3.03	2.81
Overall zone effects	1.18	2.79	For difference between EPAs $P<0.001$
For difference between *dambo* and upland areas $P<0.001$			

the 1997/98 season led to an overall reduction in attack by termites.

However, the mean number of termite-lodged plants at harvest time differed significantly across EPAs, zones, and the seed dressing and banking factors. Banking increased incidence, while seed dressing lowered it. However, the differences in mean numbers of plants affected were very slight in both cases: one to two plants per plot with respect to banking and two to three plants with respect to seed dressing. The strong significant effects must be regarded with extreme caution in this case because the differences are so marginal.

TERMITE MANAGEMENT TRIAL 1998/99

Experimental details

In the main intercrop trial in 1997/98, only a minority of farmers experienced termite attack in their fields. Fieldwork in the 1998/99 season was therefore restricted to 12 farmers who had experienced high levels of termite damage in previous years. Farmers from Chiradzulu *dambo* were not included.

Two interventions were used for the management of termite damage to maize: avoiding the use of banking, and the use of seed priming (soaking seed overnight in water) to speed up germination. The 1998 External Review of the FSIPM Project had suggested that smallholders could benefit from the application of simple agronomic techniques such as seed priming and detasselling of maize as a means of improving maize yields at low cost. Seed priming has been shown to

Table 13. Distribution of plots across the banking treatment factor (1998/99)

Treatment	Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*
No banking	6	6	4
Plots banked	10	10	12
Total	16	16	16

result in faster and stronger plant development, leading to increased yield and earlier harvest. It is already used by farmers to achieve faster germination when reseeding maize fields. It was hypothesized that seed priming might lead to a reduction in termite damage by producing more robust plants and permitting an earlier harvest. However, the expected additional yield was seen as an important potential benefit in its own right. There were, therefore, two treatment factors:

- banking: Yes or No;
- seed priming: Yes or No.

In each farm four plots were used, each having a different banking and seed priming condition. In the actual trial, however, farmers did not bank plots as initially planned. The actual distribution of plots across the banking treatment factor appears in Table 13.

Maize yield data analysis

Five responses were considered for analysis. These were:

- usable grain weight (kg/ha), including grain salvaged from fallen termite-lodged cobs, and adjusted for stolen cobs and moisture content;
- average weight/cob (kg), i.e. ratio of the weight of cobs on standing plants and fallen termite-lodged plants (adjusted for stolen cobs) to the number of cobs standing, lodged and stolen;
- number of cobs/plant, i.e. ratio of the number of cobs harvested from standing plants to the number of standing plants with cobs;
- average plant height (m) of five randomly selected plants from net plot at harvest;
- potential grain loss to termites calculated at harvest (assuming no salvage).

This is calculated as: grain loss =

$$\left(\begin{array}{l}\text{proportion of}\\\text{cob yield}\\\text{salvaged from}\\\text{termites}\end{array}\right) \times \left(\begin{array}{l}\text{usable grain}\\\text{weight, i.e.}\\\text{first response}\\\text{above}\end{array}\right)$$

Mean values for each of these responses by zone/EPA and by the banking and seed priming treatment factors are shown in Tables 14 and 15.

The summary data above make no allowance for other sources of variation that reside in the data, e.g. the farmer-

Table 14. Mean values of yield responses across banking levels (1998/99)

Yield response	Banking	Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*
Usable grain weight (kg/ha)	No	2810	1585	720
	Yes	2196	1517	1486
Weight/cob (kg)	No	0.180	0.130	0.064
	Yes	0.163	0.121	0.111
No. cobs/plant	No	1.049	0.995	0.978
	Yes	0.941	1.008	0.976
Mean plant height (m)	No	1.67	1.58	1.33
	Yes	1.65	1.53	1.52
Potential grain loss due to termites (kg/ha)	No	100.5	79.5	4.5
	Yes	140.2	50.5	18.8

Table 15. Mean values of yield responses across seed priming levels (1998/99)

Yield response	Seed priming	Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*
Usable grain	No	2479	1581	1160
Weight (kg/ha)	Yes	2374	1503	1428
Weight/cob (kg)	No	0.172	0.125	0.096
	Yes	0.167	0.123	0.102
No. cobs/plant	No	0.952	1.020	0.947
	Yes	1.011	0.986	1.001
Mean plant height (m)	No	1.62	1.55	1.46
	Yes	1.69	1.55	1.48
Potential grain loss due to termites (kg/ha)	No	131.7	69.8	0.9
	Yes	119.0	53.0	26.6

Table 16. Predicted mean usable grain weight (kg/ha) under banking and seed priming treatments (1998/99)

Treatment		Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*	*P*
Banking	No	2815	1585	720	<0.001
	Yes	2190	1717	1306	
P		<0.001	0.403	0.002	
Seed priming	No	2444	1720	1055	0.053
	Yes	2254	1642	1323	
P		0.213	0.603	0.080	

to-farmer variability. Statistical modelling procedures were undertaken to investigate effects of both banking and seed priming treatments allowing for the farmer-to-farmer variation. The analysis also investigated possible interactions with the area and type of field from which the data arose. Results are given below for the major yield response variable, i.e. usable grain weight in kg/ha.

The analysis concerning usable grain yields showed strong evidence of a banking by zone/EPA interaction ($P<0.001$) and a marginal interaction between the zone/EPA and the seed priming effects ($P=0.053$). Corresponding adjusted means are shown in Table 16.

The detrimental effect on yields caused by banking was evident only in Chiradzulu upland ($P<0.001$), not in Matapwata. In fact yields are significantly higher with banking in Matapwata *dambo*. Seed priming appears to have no effect on yields in any of the areas.

Termite damage during the season (1998/99)

Data on the number of maize plants dead or damaged by termites and other pests were recorded in the period between mid-December 1998 and early April 1999, approximately 2 weeks apart. In total there were eight sampling

Table 17. Termite lodging at plot/plant level over sampling occasions (1998/99)

Sampling occasion	Percentage plots with lodging (*n* = 48)	Percentage plants killed by termites (*n* = 3800–4300)
16–23 Dec 1998	0	0
8–11 Jan 1999	0	0
22–23 Jan 1999	4.2	0.05
9–14 Feb 1999	6.3	0.14
27–28 Feb 1999	12.5	0.41
13–15 Mar 1999	20.8	0.80
24–27 Mar 1999	47.9	1.08
8–10 Apr 1999	41.7	1.91

Table 18. Percentage of plant deaths due to termites across banking and seed priming treatments (1998/99)

Sampling occasion	Banking		Seed priming		Mean no. plants/plot (live + dead)
	No	Yes	No	Yes	
16–23 Dec 98	0	0	0	0	89.2
8–11 Jan 99	0	0	0	0	89.5
22–23 Jan 99	0	0.07	0.09	0	86.2
9–14 Feb 99	0	0.21	0.22	0.05	88.6
27–28 Feb 99	0.29	0.46	0.32	0.49	87.4
13–15 Mar 99	0.23	1.07	0.85	0.75	86.0
24–27 Mar 99	1.25	1.00	0.91	1.27	84.6
8–10 Apr 99	2.63	1.53	1.93	1.88	80.9
Totals	4.25	4.23	4.20	4.25	

occasions. The net plot germination stand count was taken (as in previous years) as the maximum of the stand counts, and dead plants were recorded at the first two sampling occasions. Percentage of plants germinating (out of a total of 120 seeds planted, i.e. 3 seeds/40 planting stations/plot) varied from 74 to 78% in the three areas. There appeared to be little difference in germination rates across banking and seed priming, except in Matapwata uplands where seed-primed plots gave a slightly lower germination rate (70%) compared with non-primed plots (76%).

Over the season, all farmers experienced plant mortality due to termites in at least one of the research plots. Three of the 12 farmers had plant deaths in all four of their plots. Basic summaries concerning plant deaths and damage to live plants by termites are presented in Tables 17 and 18.

The proportion of plots affected by termites was compared across banking and seed-priming treatments using chi-squared tests. The results are shown for plots with plant deaths by termites (Table 19), and for those with termite damage to live plants (Table 20). Plot incidence does not vary significantly across either banking or seed priming.

Plant deaths due to termites were modelled as a proportion of the initial germination rate using a generalized linear model with a binomial error structure. There was insufficient evidence of a banking effect or of a seed priming effect (P=0.402 and 0.909, respectively). There was also no evidence of an interaction of these two factors with the trial location. However, the overall percentage of deaths varied significantly across locations (P<0.001), with Chiradzulu upland fields having mean losses as high as 9% with banking, while deaths never exceeded 5% in Matapwata. The results are shown in Table 21.

An analysis similar to the above was carried out for the number of live plants damaged by termites. Here all treatment comparisons, except the seed priming treatment, were non-significant. A significant increase in overall termite damage (P=0.056) was found with seed priming. However when the results are disaggregated by land type and EPA, the effect is non-significant (Table 22). The interaction of seed priming with area was found to be non-significant (P=0.389), but it is clear that the seed-priming effect was largely in the uplands. In Matapwata *dambo*, damage to live plants by termites was less than 1%, with a slight reduction when maize seeds were primed.

Table 19. Number (and percentage) of plots with plant deaths by termites (1998/99)

Plots	Banking		Seed priming	
	No	Yes	No	Yes
With no deaths by lodging	3 (19%)	12 (37%)	6 (25%)	9 (37%)
With deaths by lodging	13 (81%)	20 (63%)	18 (75%)	15 (63%)
P	0.186		0.350	

Table 20. Number (and percentage) of plots with live plants damaged by termites (1998/99)

Plots	Banking		Seed priming	
	No	Yes	No	Yes
With no deaths by lodging	9 (56)	21 (66)	16 (67)	14 (58)
With deaths by lodging	7 (44)	11 (34)	8 (33)	10 (42)
P	0.527		0.551	

Table 21. Predicted percentage of plant deaths by termites across locations and treatment factors (1998/99)

Treatment factor	Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*
No banking	5.6	0.8	4.8
Plots banked	8.9	1.1	3.6
P	0.351	0.493	0.893
No seed priming	7.6	1.2	3.7
Seed priming done	7.1	1.3	3.6
P	0.898	0.847	0.951

Table 22. Predicted percentages of live plants damaged by termites across locations and treatment factors (1998/99)

Treatment factor	Chiradzulu Upland	Matapwata Upland	Matapwata *Dambo*	Overall
No banking	10.6	1.3	0	4.5
Plots banked	11.2	1.6	0.7	4.5
P	0.646	0.595	1.000	0.41
No seed priming	7.6	0.6	0.1	3.3
Seed priming done	12.9	2.0	0.4	5.7
P	0.200	0.150	0.132	0.056

Farmer monitoring of trial performance (1998/99)

Monitoring questionnaires

The 12 farmers participating in the termite trial were interviewed twice during the season, first just after maize emergence (15 December 98–7 January 99) and again just before harvest (14–22 April 99) (Kapulula and Lawson-McDowall, 1999). At the first interview farmers in general felt that their own maize was doing better than in the trial plots, owing to earlier planting. All farmers reported that seed priming caused them no problems, and 11 out of 12 understood the purpose of the practice, although only one farmer mentioned this when replying to a question asking what they hoped to learn from the plots. When asked the purpose of not banking, 10 out of 12 farmers mentioned the link between banking and termite lodging of maize.

At the second interview, farmers were asked to score the plots for visible termite damage on a 1–5 scale (where 1 = no damage and 5 = very serious damage) without any discussion of plot treatments. Farmers were also asked to score the rest of the field. Responses indicated that there was more damage in the rest of the field (mean score 2.7) than in the research plots (highest mean score 1.8 for unbanked and seed-primed plots). Two farmers complained of wind lodging. In at least one other instance, a farmer attributed lodging caused by wind in an unbanked plot to termites, although the roots were not cut.

When asked which plots were expected to give the best yield, farmers' responses favoured the banked plots in 12 out of 18 cases (66.7%), with equal numbers being primed or unprimed. Unbanked, primed plots were favoured in 22% of cases, but only two unbanked, unprimed plots were expected to give best yields (11% of cases). Farmers had a range of explanations for their choices which reflected environmental variability. However, banking was consistently seen as a reason for good plot performance (Table 23).

Comparison of farmers' perceptions of which plots had received which treatments with researchers' records showed that five out of 12 farmers mis-remembered the banking practice on a total of 10 out of 48 plots. This may be partly explained in some cases by banking having been carried out by another family member. No farmers mentioned the presence of primed seed as a treatment on any plot, probably because the activity had taken place at planting, several months earlier, was quite routine and did not give rise to any expectation of significant benefits.

Variation in farmers' practices within the trial

A separate study was also made of participating farmers' cultural practices at second weeding in relation to termites (Orr and Jere, 1999). Variations in weeding practices are shown in Table 24. Three farmers were found to have banked all four plots, including the two which should have received *kukwezera* weeding. One other farmer carried out *kusenda* on all four plots. Researchers concluded that these farmers were making rational decisions to increase yield because, in the absence of termite damage, banking (or *kusenda)* was the best practice, especially given heavy rain eroding

Table 23. Farmers' responses (% of cases) when asked to choose the best performing plot(s) out of 48 across four treatments (banked/unbanked, seed primed/unprimed) (1998/99)

	Banked plots rated best	Unbanked plots rated best	Total plots chosen as 'best plots' (total available)
Maize seed primed rated best	33.33 (15)	22.22 (9)	55.55 (24)
Maize not seed primed rated best	33.33 (17)	11.11 (7)	44.44 (24)
Total plots chosen as 'best plots' (total available)	66.66 (32)	33.33 (16)	99.99 (48)

Numbers in parentheses are the number of plots with a given treatment combination in the trial.

Table 24. Farmers' alternatives to banking (*kubandira*) as a form of second weeding in relation to risk of termite damage in the 1998/99 termite trial

Type of weeding (no. trial farmers using)	Description of practice	Effects/costs/benefits
Kubandira (banking) (3)	Soil and weeds are scraped up both ridge sides from furrow and weeds are buried at ridge top	Buries weeds near maize plant. Encourages termites under dry conditions. Strengthens plant roots and improves drainage under wet conditions
Kusenda (half-banking) (1)	Soil and weeds are scraped up one side of the ridge from the furrow and deposited at ridge top	Less labour and fewer rotting weeds placed close to the maize plant than with *kubandira*. Can be done rapidly when late weeding
Kukwezera/Kukweza (6)	Soil scraped up ridge but weeds shaken out and laid in the furrow to dry	Fewer termites (if present) since fewer rotting weeds near maize roots; but with heavy rain, more weed growth and survival of weeds, more erosion, lodging and fertilizer leaching
No second weeding (2)		Discourages termites if present; saves labour and time if early weeding was effective, but more weed growth, more rain erosion and maize lodging

Source: Orr *et al.* (1999).

the ridge or delay in weeding leading to excessive weed growth. For the purpose of the on-farm trial treatment structure, not weeding at all, *kukwezera* and *kukhweza* were all classed as equivalent to 'not banking', while *kusenda* was equated with *kubandira*.

CONCLUSIONS FROM THE 1998/99 TRIAL

Termite foraging and damage incidence

Once again in 1998/99, termite damage to maize was quite minor, largely owing to good rains which continued into April. The available information on foraging patterns of *Macrotermes* species (the main perpetrators of the maize lodging seen in trial plots) has been summarized by Lepage (1982). In general, *Macrotermes* nests are overdispersed and nest territories (of about 0.1–0.3 ha) are contiguous, such that all available habitat is within the territory of a nest. A permanent system of underground tunnels allows the termites to forage in any part of the nest territory at any time. On any given night foraging occurs in only a small part of the territory, and on successive nights most of the area of the territory is visited.

The intensity of foraging activity is determined by the development needs of the nymphal brood, culminating in the release of reproductive adults at the start of the rains. The maximum intensity of foraging, therefore, occurs during the dry season while the nymphs are developing. In general, foraging is more intense at higher temperatures and is inhibited by periods of rain. Our data show that in southern Malawi foraging is most intense from April onwards, the period when the maize is ripening and rainfall is declining.

It follows that a season with lower than average rainfall will encourage termite foraging, but the farmer cannot predict exactly where or when damage will take place. Fields which, on the basis of past experience, are known to be within the territory of a vigorous mound are likely to be weeded without banking, especially if the farmer already sees soil sheeting covering foraging galleries on the soil surface (Orr *et al.*, 1999).

Farmers can and do pick up lodged maize plants and stook them or harvest their cobs, even when unripe. This is likely to reduce the losses associated with later (usually more severe) termite damage. The earlier the damage starts, the less likely it is that the farmer will be able mitigate the losses, however.

It is evident that there are very serious difficulties involved in demonstrating the effect of an IPM strategy using on-farm trials in a context where damage varies both over short distances (even within a single field) owing to termite foraging patterns, and from season to season depending on rainfall patterns. Farmers have to make the decision whether or not to bank within a defined period (approximately 4-8 weeks after planting) if they are not to lose yield due to excessive weed development, ridge erosion and wind lodging.

Even within a formal trial, farmers are unwilling to forego the expected benefits of a specific practice which is perceived as beneficial, even when this is excluded by the experimental design. While this *ad hoc* decision-making is problematic within an experiment, it nevertheless demonstrates the flexibility with which farmers can address changing crop management scenarios.

Farmers have a range of alternatives to full banking which suppress weeds but do not place rotting organic matter near to maize plants (Orr and Jere, 1999). As these practices are all less labour-demanding than full banking, the only costs associated with them are likely to be reduced yield or, in some cases, the inability to carry out *mbwera* and grow a relay crop of field peas or beans.

The alternative management strategy of destroying the termite colony by killing the queen, as sometimes practised by farmers (Orr and Jere, 1999), is unlikely to be widely adopted. Firstly, nests of *Macrotermes falciger*, the commonest *Macrotermes* species in Blantyre/Shire Highlands, are very large (up to 5 m high and 10 m in diameter) and systematically locating the queen cell is almost impossible, whereas it is somewhat more feasible in other *Macrotermes* species. Even if the queen is destroyed, the colony may repair the damage and rear one or more new queens. Secondly, the annual production of winged reproductive adults (alates) from a large *Macrotermes* nest amounts to several kilograms. This represents a significant source of food and income for a resource-poor farmer (Logan, 1992; Orr and Jere, 1999).

CONCLUSION

Pest management for low-value smallholder crops seldom offers unequivocal advantages for resource-poor farmers. Given the uncertainties attending the severity and timing of termite damage to maize, farmers and extension personnel need to be given information about the range of possible cultural options which may be appropriate in different circumstances, including not only termite damage but also a range of other factors such as weed development, rainfall and ridge erosion. Farmers will then select from the menu of options, depending on the crop stage at which they become aware of termite damage and their perception of its severity.

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DISCUSSION

A. Orr. Your abstract states "...in all 3 years termite attack was sporadic... and significant treatment effects could be demonstrated only occasionally". What are the implications for on-farm trials? Do we continue with the same experimental approach? Do we focus on 'hot spot' areas? Or do we adopt a different approach and go for a thorough investigation of the range of practices that farmers use to produce a menu of alternatives.

J. M. R. Each of these responses could be appropriate in different circumstances. For termites specifically we tried to use 'hot spots' but the season was unsuitable for verification even though the termite populations are still present. It would appear most useful now to develop materials to brief extensionists on the options for weeding practices and the likely outcomes under different circumstances.

A. J. Sutherland. When validating existing farmers' pest control methods there is a need to be careful in using a 'hot spot' approach, as one may have to ask them not to do what they know is best. It is more appropriate if new ideas (which could be based on local knowledge introduced from another area) are being tried out at 'hot spots'.

C. Chibwana. A message on available weeding options from which farmers could choose an appropriate strategy for their particular situations would be useful as it will: (i) equip extension workers with information that would allow them to advise farmers with confidence – at the moment this information is not documented in a manner that is available; and (ii) help farmers to understand their own practices and choose their weeding options strategically.

C. R. Riches. There seems to be a conflict between trying to learn from farmers about the pest control practices they use and then judging the value of a practice on the basis of 1 year of experimentation. There may well be pressures to find a positive result, but farmers' 'best-bet' practices have been developed over a range of seasons and environmental conditions and reflect the balance of probabilities that a pest problem may occur in a particular season. On the other hand, on-farm trials have been used to accept or reject a practice on the basis of one season in a single environment.

J. M. R. Kaselera was abandoned after 1 year in favour of *mbwera* which is a similar technique already used in Matapwata. In the end, similar approaches were tested over three seasons. I agree, though, that we are forced by the nature of the 3-year project cycle to be highly selective and discontinue activities which could have been continued.

V. Saka. Did you observe any relationship between farmer-developed cultural pest management strategies for termites and burial of crop residues?

J. M. R. Crop residue burial is almost universal and takes place before maize planting. Termite damage mainly occurs much later, at maize maturity, when the residues have long since disappeared.

C. S. M. Chanika. Farmers' practice with crop residues is done in such a way that decomposition will take place before planting, therefore it is unlikely to be associated with termites which are attracted to undecomposed materials.

A. M. Chirembo. It is important to realize that termite distribution in the field is not uniform. It was important to find the 'hot spot' for a well laid experiment for studying banking versus no banking. However, it seems logical to produce a message for the farmers on when to bank and when not to bank, depending on the circumstances.

J. M. R. In 1998/99 we concentrated on farms where termite damage had been found in the previous two seasons. However, the high rainfall during the season greatly reduced damage levels so that effects of banking were not obvious.

Pod pests and yield losses in smallholder pigeonpea in Blantyre/Shire Highlands

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ABSTRACT

Surveys of pod pests in Malawi have shown seed damage levels of up to 23% in 1995 and 1996. In 1997/98, disappointing pigeonpea yields in the Farming Systems Integrated Pest Management (FSIPM) Project area were thought to be due to pod pests, especially sucking bugs. To investigate pod damage levels within the project area, surveys of pigeonpea pod pests within FSIPM on-farm trial plots were carried out in June and August 1999 in Blantyre/Shire Highlands Rural Development Project (RDP) area. The first trial with 42 farmers in Chiradzulu North and Matapwata Extension Planning Areas (EPAs) was set up to compare the performance of ICRISAT pigeonpea varieties, ICEAP 00040 and ICEAP 00053, with ICP 9145 as a wilt-resistant control and local pigeonpea as a check. Each farm contained one plot of each variety in a RCB design. A second set of trials in Mangunda section of Matapwata EPA had sets of four medium duration varieties, ICEAP 00068, ICEAP 73, ICP 6927 and Chilinga (a farmers' variety) in a randomized block on each of five farms. A second and third block on each farm had long duration varieties, ICEAP 00040, ICEAP 00053 with ICP 9145, either intercropped with maize (fertilized at 50 kg N/ha) or sole cropped. Pod samples were examined for seed damage by bugs, pod-boring Lepidoptera and pod-boring fly larvae. During August and September 1999, field collection of pod-boring caterpillars and their natural enemies was undertaken at the same sites as the damage survey. Larval and pupal pod borers were reared to adult where possible and identified to species level. Percentage data for seed damaged by bugs, borers and pod flies were analysed using generalized linear modelling. Pigeonpea varieties have been compared in terms both of these modelled percentages and also using odds ratios which define the relative chance of damage for different varieties. Pod damage results from Mangunda were higher than elsewhere. Among medium duration varieties, bug damage affected 38–52% of seeds, while borer damage was 2–7%. External pod damage affected 7–37% of pods. Damage by pod flies was 0.4–2.4%. Chilinga had significantly lower external pod borer damage (P=0.001) and the lowest borer damage to seeds (P=0.06). On the long duration varieties, bug damage affected 38–49% of seed under intercropping and 45–54% under sole cropping, with ICP 9145 suffering less damage than the ICEAP varieties, though not significantly so. Borer damage to seeds was 13–33% under intercropping and 15–31% under sole cropping. Across varieties and cropping patterns results were inconsistent. ICP 9145 appears to have a slight advantage under intercropping which disappears under sole cropping. In the main trial with long duration varieties, damage levels were lower than at Mangunda but higher in Matapwata than in Chiradzulu North. Local pigeonpea performed significantly better against pod pests than improved varieties (P<0.001). The worst damage once again was due to bugs (12–24%), the greatest damage occurring with ICEAP 00040 (24%). Pod borer damage was least for ICEAP 00040 and most for the local variety, though overall differences were only marginally significant (P=0.049). The data demonstrated that seed damage by pod borers can be predicted from external pod damage which may enable damage surveys to be conducted more rapidly. Farmers were asked to evaluate samples of seed with varying degrees of bug and borer damage, in terms of its usability. This was used to estimate the extent to which research surveys may over-estimate damage. It was concluded that bug damage is over-estimated by as much as 100%, while borer damage is likely to be exaggerated by not more than 20%. A diverse fauna of pigeonpea pod borers was found, which included as a common constituent the previously unrecorded noctuid moth caterpillar, *Pardasena virgulana* and the tortricid *Leguminivora ptychora*.

INTRODUCTION

After maize, pigeonpea is the second most extensively grown crop in Blantyre/Shire Highlands. Its importance to resource-poor smallholder farmers as a source of food, firewood and income and as a technology for soil nutrient replacement can scarcely be exaggerated. These issues are touched upon by Orr *et al.*, p. 279, Jones *et al.*, p. 150 and Snapp *et al.*, p. 246 and are not further explored here. The Farming Systems Integrated Pest Management (FSIPM) Project has been working for three seasons (1996/97–1998/99) with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to test improved pigeonpea varieties with farmers in Chiradzulu North (Mombezi) Extension Planning Area (EPA) and in Matapwata EPA (now in Thyolo North Rural Development Project (RDP)) using researcher-designed, farmer-managed on-farm trials, involving up to 67 participating farmers in three Sections.

The original focus of these trials was to evaluate improved pigeonpea varieties for their overall yield performance and, particularly, their resistance or susceptibility to the pathogen *Fusarium udum*, which is the most important cause of wilting and death in pigeonpea in Malawi. A pigeonpea variety trial was conducted with five farmers in Mangunda Section of Matapwata EPA in 1997/98 and 1998/99. A larger trial involving farmers from both Chiradzulu and Matapwata EPAs was also conducted within a maize/pigeonpea/bean intercropping system to study (i) varietal tolerance of bean to bean stem maggot and (ii) varietal tolerance to *Fusarium udum* in pigeonpea. Selected results of these trials have been presented at this workshop (Ritchie *et al.*, p. 164 and p. 180).

IMPORTANCE OF PIGEONPEA POD PESTS

Shanower *et al.* (1999) have reviewed the biology and economic importance of pod pests on pigeonpea. The major economic impact is caused by pod-sucking bugs (Heteroptera), pod-boring caterpillars (Lepidoptera) and pod-boring fly maggots (Diptera, Agromyzidae). Among the pod borers, *Helicoverpa armigera* (Hübner) (Noctuidae) and *Maruca vitrata* (F.) (Pyralidae), are regarded as the most serious, with annual pigeonpea losses world-wide valued at US$ 317 million and US$ 30 million, respectively. Among the pod-sucking bugs, Coreidae are dominant and *Clavigralla* spp. (especially *C. tomentosicollis*), *Anoplocnemis* spp. and *Riptortus* spp. are particularly damaging. Shanower *et al.* (1999) do not provide any estimate of financial losses but quote figures from Tanzania (Materu, 1970) citing losses in excess of 50%, while Minja (1997) found losses as high as 32% in Kenya (Coast Province). In Malawi, Minja (1997) found that *C. tomentosicollis*, *H. armigera* and *M. vitrata* were the major pod pests, with *Etiella zinckenella* Treitschke also causing concern. Overall pod pest damage levels in June 1995 and July 1996 reached maxima of 23% (Thyolo) and 20% (Mwanza), respectively. In Blantyre and Zomba Districts, damage levels ranged between 10% and 12%.

During the 1997/98 season, it was apparent at all the FSIPM Project trial sites, that although podding was generally prolific, the eventual yields of clean seed were poor and seed damage levels were high. Damage by pod-sucking bugs, in particular, was plainly visible in the form of shrivelled pods. Accordingly, in the 1998/99 season, a survey programme was mounted within the FSIPM Project trial plots to determine the incidence and severity of pod and seed damage.

CABI Bioscience, with separate funding from the Department for International Development (DFID) Renewable Natural Resources Knowledge Strategy, Crop Protection Programme, is conducting a research project to inventory the pod-boring Lepidoptera damaging pigeonpea and related grain legumes in Africa, Asia and South America, and their natural enemies. The opportunity existed, therefore, to combine the efforts of the FSIPM Project, ICRISAT (E. M.), the Department for Agricultural Research and Technical Services (DARTS) (P.M.) and CABI (A. P.) to learn more about the pigeonpea pest fauna in southern Malawi and its impact on yields.

MATERIALS AND METHODS

Experimental design of on-farm trials

The trial at Mangunda was designed by the FSIPM Project's farming systems agronomist and comprised three main plots in each of the farmers' fields. Two of the main plots had the following long duration pigeonpea varieties grown on four sub-plots within each main plot: ICP 9145 (the only wilt-resistant variety officially released in Malawi), ICEAP 00040 (wilt-resistant) and ICEAP 00053 (wilt-susceptible).

In one of the main plots, the pigeonpea plants were grown as an intercrop with maize. In the second main plot, they were grown as a sole crop. Varieties were randomly allocated to each main plot. In the third main plot, four other medium duration varieties were grown on four sub-plots, intercropped with maize. These were: Chilinga (a variety obtained from farmers in Chiradzulu) and three ICRISAT (wilt-susceptible) varieties, ICEAP 00068, ICEAP 00073 and ICP 6927. The complete treatment structure for the trial is given by Abeyasekera, p. 28.

In the main intercrop trial conducted within Chiradzulu and Matapwata EPAs, the trial design used was identical to the design used in the 1997/98 season. Design details can be found in Abeyasekera (1998). Pigeonpea varieties tested in the main intercrop trial were ICP 9145, ICEAP 00040 and ICEAP 00053. The trial was carried out on the fields of 18 farmers in Nansadi Section of Matapwata EPA and 24 farmers in Lirangwe Section of Mombezi EPA.

Data collection from on-farm trials

Surveys of pigeonpea pod pests were undertaken in both of the above trials (Table 1). The planned procedure for sampling pigeonpea pods from each plot (or sub-plot in the case of the Mangunda trial) was to destructively sample five pods at random from each of five randomly selected plants. This would give a total of 25 pods/sub-plot. In the actual sampling of medium duration varieties at Mangunda, there were too few mature pods available to take five from each of five plants. The data collection team had to select pods from several plants in order to get 25 pods in total. At least five plants were always sampled.

The 25 pods (per plot or sub-plot) were first examined for the presence or absence of external damage. Then the

Table 1. Dates and podding percentage for pigeonpea pod pest surveys

Dates	Location (Section)	Trial	Podding percentage
21–22.06.1999	Mangunda	Medium duration	35–43
16–19.08.1999	Lirangwe	Long duration	100
23–30.08.1999	Nansadi	Long duration	100
20.08.1999	Mangunda	Long duration	100

number of seeds within each pod were counted and a record made of the total number damaged or destroyed and whether the damage was caused by pod borers, pod-sucking bugs or pod flies (*Melanagromyza chalcosoma* Spencer, Minja *et al.*, 1999). The data sets presented for analysis comprised total numbers of seeds damaged per plot due to different causes for three different trials: (a) Mangunda medium duration varieties; (b) Mangunda long duration varieties; and (c) main intercrop trial pigeonpea varieties. With respect to the medium duration varieties at Mangunda, data were available for only four farmers since one farmer had planted *Fusarium*-susceptible local pigeonpea in the same field in the previous season and had unwittingly created a 'wilt sick plot' with extreme *Fusarium* wilt incidence. Since none of the medium duration pigeonpea varieties in this trial was resistant to the pathogen, plant survival was too low to permit pod collections to be made.

Collection and rearing of pod borers

During the surveys detailed above and subsequently during a visit to Malawi by A. P. (September 1999) large numbers of damaged pods of pigeonpea (from smallholder farms in Mombezi and Matapwata), *Crotalaria ochroleuca* (from Mafisi Estate, Mangunda, Thyolo RDP and FSIPM Project trial sites), and *Tephrosia vogelii* (from FSIPM Project trial sites in Matapwata) were collected and opened. Any larval or pupal borers or parasitoids were sorted into individual labelled containers with adequate food. Any adult borers and parasitoids emerging were removed and prepared, labelled as voucher specimens and identified, where possible to species level. The data gathered from this survey are at best semi-quantitative, since it was not possible to carry out a standardized destructive sampling programme. The collection effort was aimed at capturing a broadly representative sample of the different borer species damaging pigeonpea in the FSIPM Project area. Wherever possible, digital photographic images of different stages of the main borer species and their parasitoids were prepared as an aid to field identification in future surveys (see Plates 1 and 2).

During the formal pod surveys from on-farm trials and the collection of damaged pods for borer rearing and identification, the research team made qualitative observations of the occurrence of different species of pod-sucking bugs feeding on the pods of pigeonpea, *Crotalaria*, *Tephrosia* and other grain legumes.

Data analysis methodology for pod survey data

Five responses of interest were identified for analysis:

- the proportion of pods (out of 25) with visible external damage
- the proportion of seeds damaged by pod borers
- the proportion of seeds damaged by pod-sucking bugs
- the proportion of seeds damaged by pod flies
- the overall proportion of damaged seeds in selected pods.

Since these responses are all proportions, computed, for example, from numbers of seeds damaged by various pests, they were analysed via logistic regression procedures, i.e. using a generalized linear model. The analysis takes account of the fact that the numbers of seeds damaged or numbers of pods showing external damage are likely to follow a binomial distribution. One assumption in this analysis is that the chance of damage remains the same (within a particular plot) for each item examined for damage. While this might be a reasonable assumption for each of the 25 pods examined for external damage, it is possible that plants will differ in the frequency of their pod damage due to patchy pest distribution between plants. The assumption of an even distribution of damage is even less likely to be true for each of the seeds examined, since a seed from a pod with damaged seed has a greater chance of also being damaged than one from an undamaged pod. Initial analyses undertaken in fact demonstrated this to be the case as evident from statistical diagnostics for checking the goodness of fit of models used. All analyses concerning seeds and analyses concerning pod damage by external causes in most instances were, therefore, modified to take account of varying binomial probabilities across the seeds (and possibly pods).

All analysis procedures were carried out taking into account the data structure as specified by the trial design, e.g. allowing for variation between farmers in all cases, allowing for a nested data structure in the case of the long duration varieties at Mangunda, and allowing for zone and EPA differences in analyses conducted with data from the main intercrop trial.

In sections below, results are presented in terms of predicted percentages of seeds and/or pods showing damage. Results are also presented in the form of odds ratios, i.e. the odds of damage to one variety relative to the odds of damage to another variety.

In order to define formally odds ratios, we first define the odds of damage for a particular variety as:

Probability of damage / Probability of no damage
= Probability of damage / 1 – Probability of damage

Two varieties can then be compared by looking at the ratio of their odds. So for example, the odds of damage to ICP 6927 relative to Chilinga would be defined in terms of the odds ratio as:

$$[P_1/(1-P_1)] \,/\, [P_2/(1-P_2)]$$

where P_1 = probability of damage for variety ICP 6927 and P_2 = probability of damage for variety Chilinga.

RESULTS OF POD DAMAGE SURVEY

Medium duration varieties (intercropped with maize) at Mangunda

The results from fitting a series of generalized linear models to the numbers of seeds/pod damaged among medium duration varieties at Mangunda are shown in

Table 2. Predicted percentages of seeds/pods showing damage for medium duration varieties at Mangunda

Variety	Pods with external damage (%)	Damaged by pod borers (%)	Damaged by pod-sucking bugs (%)	Damaged by pod flies (%)	Overall damage (%)
Chilinga	7.0	2.0	39.0	0.41	41.7
ICEAP 00068	36.7	7.3	38.1	1.35	47.2
ICEAP 00073	14.0	2.3	45.0	1.16	48.5
ICP 6927	35.0	7.2	52.5	2.42	62.2
Sample size range	23–25	118–153	118–153	118–153	118–153
P	<0.001	0.060	0.321	0.333	0.168

Table 3. Odds ratios for comparing ICP varieties with Chilinga for medium duration varieties at Mangunda

Variety compared with Chilinga	Pods with external damage	Damaged by pod borers	Damaged by pod-sucking bugs	Damaged by pod flies	Overall damage
ICEAP 00068	7.79	3.80	0.96	3.34	1.25
ICEAP 00073	2.17	1.12	1.28	2.84	1.32
ICP 6927	7.22	3.73	1.74	6.11	2.30

Table 2. The table shows model predictions for the percentage of seeds and pods showing damage.

Clearly pod-sucking bugs are a major problem for all varieties included in the trial. There is some indication that varieties Chilinga and ICEAP 00073 show greater resistance to pod borers than ICEAP 00068 and ICP 6927. Pod fly attack also seems lower for Chilinga and ICEAP 00073. With respect to overall damage, ICP 6927 shows a significant difference (P=0.043) only with respect to Chilinga. Overall the variety Chilinga appears to be the least susceptible to pod pests.

Table 3 shows the odds of damage to varieties ICEAP 00068, ICEAP 00073 and ICP 6927 relative to Chilinga. Values greater than 1 indicate a higher rate of damage to the variety listed compared with damage to Chilinga.

To illustrate the interpretation, consider the final column in Table 3. The odds of external damage to pods of variety ICEAP 00068 are nearly eight times higher compared with damage to Chilinga. On the other hand, for ICEAP 00073, the odds of external damage are only about twice as high as for Chilinga. The survey of medium duration varieties was carried out in late June when less than half the pigeonpea plants were podding (Table 1). It seems likely that pod damage will have continued to worsen until all seed pods were fully dry or were harvested. The figures given here are, therefore, most likely an under-estimate of the eventual full damage.

Long duration varieties (sole or intercropped with maize) at Mangunda

The experimental set up for the long duration varieties planted in the Mangunda trial involved two main plots within each farm, five farms in all. On one main plot, pigeonpea was grown as an intercrop with maize while in the other, it was grown as a sole crop. Each main plot had three subplots on which ICP 9145, ICEAP 00040 and ICEAP 00053 were grown.

Generalized linear modelling procedures, allowing for varying binomial probabilities, were carried out for each of the response variates listed above. However, the model fitting procedure failed to converge for the proportion of seeds damaged by pod flies, since the incidence was very low and only one farmer had any pod fly damage amongst sampled seeds. The results below, therefore, refer only to the remaining four responses.

The initial analysis involved studying differences in damage proportions across two cropping patterns (sole or intercrop) and across the three pigeonpea varieties. It was also interesting to see if there was an interaction between these two factors, i.e. whether variety differences varied across cropping patterns. The latter interaction was found to be non-significant with respect to all damage responses investigated. However, predicted percentages of damage due to different causes indicated some apparent interaction effect. Results are, therefore, reported separately in Table 4 for intercropped and sole cropped pigeonpea.

As for the medium duration varieties, pod-sucking bugs are again the most damaging pest attacking pigeonpea seeds. The severity of damage appears to be higher when pigeonpea plants are sole cropped than when they are grown as an intercrop. The difference is, however, non-significant (P=0.344).

The interaction of cropping pattern with pigeonpea variety is non-significant with respect to the proportion of pods with external damage (P=0.113). However, results above indi-

Table 4. Predicted percentages of seeds/pods showing damage for long duration varieties at Mangunda

Cropping pattern	Variety	Pods with external damage (%)	Damaged by pod borers (%)	Damaged by pod-sucking bugs (%)	Overall damage (%)
Intercrop	ICP 9145	12.8	5.3	37.6	43.
	ICEAP 00040	20.0	7.1	48.9	56.1
	ICEAP 00053	32.8	10.8	44.5	56.5
P for differences between intercropped varieties		0.071	0.207	0.217	0.110
Sole crop	ICP 9145	31.2	10.4	45.2	57.2
	ICEAP 00040	15.2	5.1	53.5	58.7
	ICEAP 00053	25.6	9.4	54.4	64.1
P for differences between sole cropped varieties		0.355	0.485	0.453	0.691
Sample size range		25	109–151	109–151	109–151
P for cropping pattern		0.757	0.831	0.344	0.373

Table 5. Odds ratios for comparing ICEAP varieties with ICP 9145 at Mangunda

Cropping pattern	Variety	Pods with external damage	Damaged by pod borers	Damaged by pod-sucking bugs	Overall damage
Intercrop	ICEAP 00040	1.70	1.36	1.59	1.69
	ICEAP 00053	3.33	2.16	1.33	1.72
Sole crop	ICEAP 00040	0.40	0.47	1.39	1.07
	ICEAP 00053	0.76	0.89	1.45	1.34

cate that ICP 9145 when intercropped with maize, is less damaged than the ICEAP varieties, but more damaged than the ICEAP varieties when it is sole cropped. As an intercrop, ICP 9145 has some advantage over ICEAP 00053 (P=0.032) with visible damage on pods being substantially less by about 60%. ICEAP 00040 appears to suffer less external damage than ICP 9145 when these varieties are grown as sole crops, but the observed 50% reduction is non-significant (P=0.313). It is important to note, however, that non-significance can result from high plot-to-plot variability as is often evident under on-farm conditions. Therefore, in interpreting the above results, it is important not to dismiss non-significant differences in damage percentages as being truly absent.

Interpretation is aided by looking at the odds ratios for the two ICEAP varieties relative to variety ICP 9145 as shown in Table 5. With respect to overall damage and damage by pod-sucking bugs, the ICEAP varieties have slightly worse odds of damage compared with variety ICP 9145. The odds of damage by pod borers and visible external damage to pods is much higher for ICEAP 00053 compared to ICP 9145 when these varieties are intercropped with maize. The advantage of ICP 9145 disappears, however, when pigeonpea is sole cropped.

Long duration varieties (intercropped) in the main intercrop trial

Data on pod pests were also collected from farmers included in the main intercrop trial aimed at studying pest tolerance among four bean varieties and *Fusarium* wilt tolerance among four pigeonpea varieties, i.e. a local variety, ICEAP 00053, ICEAP 00040 and ICP 9145. Here, farmers came

Table 6. Predicted percentages of seeds/pods showing damage for long duration varieties grown in the main intercrop trial

EPA	Pods with external damage (%)	Damaged by pod borers (%)	Damaged by pod-sucking bugs (%)	Damaged by pod flies (%)	Overall damage (%)
Chiradzulu	10.3	3.1	14.7	0.5	18.4
Matapwata	22.7	9.2	20.5	2.5	32.2
P for EPA diff	<0.001	<0.001	<0.001	<0.001	<0.001
Odds of damage in Matapwata relative to Chiradzulu	2.54	3.16	1.50	5.15	2.11

Table 7. Predicted percentages of seeds/pods showing damage for long duration varieties grown in the main intercrop trial

Variety	Damaged by pod-sucking bugs (%)	Damaged by pod flies (%)	Overall damage (%)
Local	11.6	0.8	17.3
ICEAP 00053	16.0	1.1	23.4
ICEAP 00040	23.8	1.5	30.4
ICP 9145	14.7	1.2	20.7
P	<0.001	0.046	<0.001

Table 8. Odds ratios for ICEAP 00053, ICEAP 00040 and ICP 9145 compared to the local variety based on pod pest damage recorded in the main intercrop trial

Variety compared with local variety	Damaged by pod-sucking bugs	Damaged by pod flies	Overall damage
ICEAP 00053	1.45	1.45	1.46
ICEAP 00040	2.38	1.98	2.09
ICP 9145	1.31	1.54	1.25

from two EPAs and their fields were classified as being either *dambo* or upland. The effect of these two factors and their interaction were also studied during the analysis relative to the farmer-to-farmer variation, while pigeonpea varietal tolerance was studied relative to the plot-to-plot variation.

For each of the responses analysed, EPA effects were clearly evident ($P<0.001$) with a higher incidence of pod/seed damage in Matapwata compared to Chiradzulu. Table 6 summarizes the results in terms of predicted percentages of damage to seeds or pods, as well as the odds of damage in Matapwata relative to Chiradzulu.

The odds of damage in Matapwata, relative to Chiradzulu, are worst for pod flies, being about five times greater. Odds ratios are also found to be approximately three times higher in Matapwata, compared to Chiradzulu, for pod borers and for pods showing external damage.

In comparing the severity of pod pests among different varieties included in the trial, clear effects were found ($P<0.001$) for both the overall percentage of damaged seeds and the percentage of seeds damaged by pod-sucking bugs. There was some evidence ($P=0.046$) of a variety effect also with respect to damage caused by pod flies. The local variety gave the lowest damage percentages in all cases (Table 7).

Table 8 shows that the odds of damage to variety ICEAP 00040 is about twice the odds of damage to the local variety with respect to overall seed damage, seed damage due to pod-sucking bugs and seed damage due to pod flies. The relative increases in odds of damage for ICEAP 00040 compared to the local variety were significant for all these three responses ($P<0.001$, $P<0.001$ and $P=0.007$, respectively). However, the odds of damage were only about 1.5 times higher for ICEAP 00053 relative to the local variety ($P=0.002$, $P=0.004$ and $P=0.163$, respectively). Odds of damage for ICP 9145 were only slightly higher than the odds of damage for the local variety ($P=0.066$, $P=0.035$, $P=0.103$, respectively).

With respect to the proportion of seeds damaged by pod borers and the proportion of pods showing external damage, there was insufficient evidence of an overall variety effect when averaged over EPAs. However, there was some evidence of an EPA by variety interaction ($P=0.047$ and $P=0.014$, respectively) for these two responses.

Corresponding results, shown in Tables 9 and 10, clearly show the reason for the variety by EPA interaction. The local variety is poor compared to the ICRISAT varieties in Chiradzulu but is much better relative to those varieties in Matapwata. ICP 9145 gives the most consistent results across the two EPAs. It has a significantly lower percentage of pods with external damage in Chiradzulu compared to the local variety ($P=0.014$) while in Matapwata, the corresponding percentage is only marginally worse compared to the local variety ($P=0.089$). Damage by pod borers does not vary significantly across varieties in Matapwata. However, in Chiradzulu, the local variety had significantly more pod borer damage than variety ICP 9145 ($P=0.029$). For variety ICP 9145 in Chiradzulu, the odds of seed damage by pod borers, is about half that of the local variety. It appears that while the local variety is slightly more damaged in the poor growing conditions of Matapwata (wetter and cooler) than in Chiradzulu, the ICRISAT varieties experience a 2–3-fold

Table 9. Predicted percentages of seeds/pods showing damage for long duration varieties grown in the main intercrop trial

Variety	Chiradzulu		Matapwata	
	Pods with external damage (%)	Damaged by pod borers (%)	Pods with external damage (%)	Damaged by pod borers (%)
Local	13.9	4.2	17.1	7.0
ICEAP 00053	12.2	3.6	26.1	11.1
ICEAP 00040	8.7	2.6	24.0	9.0
ICP 9145	6.6	2.0	23.5	9.7
P	0.049	0.103	0.105	0.176

Table 10. Odds ratios for comparing the local variety with the ICRISAT varieties in the main intercrop trial

Variety compared with the local variety	Chiradzulu		Matapwata	
	Pods with external damage	Damaged by pod borers	Pods with external damage	Damaged by pod borers
ICEAP 00053	0.86	0.87	1.72	1.66
ICEAP 00040	0.59	0.63	1.53	1.32
ICP 9145	0.44	0.47	1.49	1.43

increase in damage, perhaps owing to their preference for hotter, drier conditions.

Predicting seed damage from external pod damage

Data from the main intercrop trial were also analysed to investigate whether pigeonpea seed damage could be predicted from pod damage. The prediction relationships were quite strong with fitted regression lines for each EPA as follows:

$y = -0.00056 + 0.3078x$ in Chiradzulu

$y = -0.00072 + 0.4372x$ in Matapwata.

Table 11 gives predictions for the percentage of seeds damaged, derived from the percentage of pods with visible external damage. The precision of the predictions was high. The predictions for Chiradzulu were within 9% to 13% of the true values, while for Matapwata, the predictions were within 9% to 16% of the true value. Figures 1 and 2 show the form of the relationship. The relationship was more or less the same for all varieties.

Levels of seed damage

The pod damage survey reported here counted individual seeds with any damage from borers and pod-sucking bugs as a total loss. This is convenient for scoring purposes but does not provide an accurate picture of the true losses experienced by farmers who are able to utilize some categories of damaged seed.

Mwale *et al.* (1999) elicited responses from farmers to a graded series of pod and seed samples with slight to severe damage by pod bugs and pod borers (Ritchie, unpublished data) derived from the material examined during the pod damage surveys reported here. Farmers were asked to classify the seed samples according to the purposes for which they could be used. They separated seed samples into one or more of five potential use categories: planting, sale, home consumption, livestock feed and rejected seed. Subsequent analysis of these responses involved counting seed fed to livestock as a total loss, while seed used for domestic consumption, even if not suitable for

Table 11. Percentage of seeds damaged by pod borers, predicted from percentage externally damaged

EPA	Externally damaged (%)						
	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Chiradzulu	3.0	5.9	8.7	11.6	14.4	17.3	20.1
Matapwata	4.3	8.2	12.0	15.9	19.8	23.7	27.6

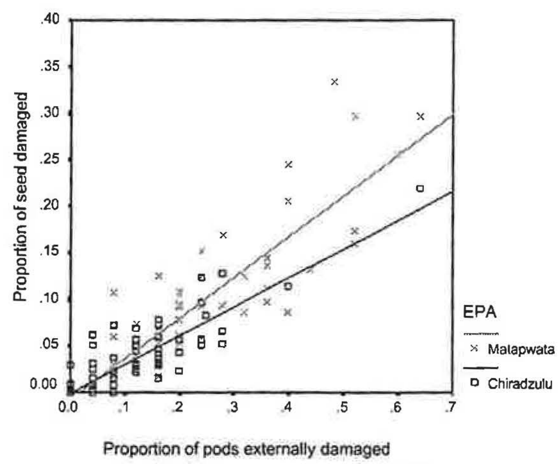

Figure 1. Relationship between proportion of seed damaged by pod borers and the proportion of pods showing external damage (by EPA).

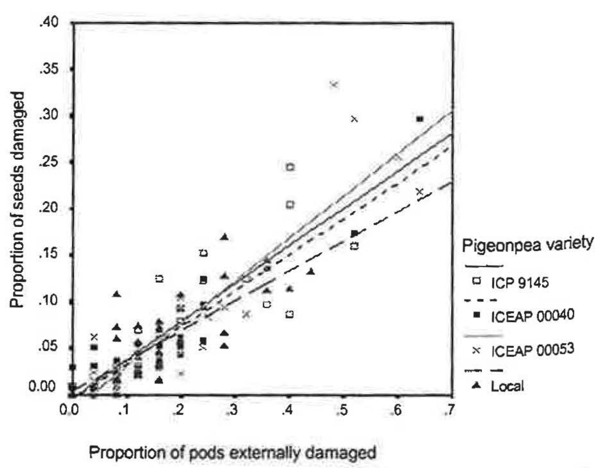

Figure 2. Relationship between proportion of seed damaged by pod borers and the proportion of pods showing external damage (by variety).

Table 12. Farmers' perceptions of seed damage from pod-sucking bugs

Farmers' perception	Percentage damage 10–15†		>30‡		>60§	
	No.	%	No.	%	No.	%
Usable*	14	93.33	9	60	0	0
Useless	1	6.67	6	40	15	100
Total	15	100	15	100	15	100

*Could either be cooked, sold or planted.
†Mature seeds with slight discoloration or small dent. When cut open, 10–15% of seed surface necrotic.
‡Mature seeds clearly dented and discoloured When cut open, more than 30% of seed necrotic.
§Mature seeds seriously dented and discoloured. When cut open, more than 60% of seed necrotic.

sale or planting is counted as having full value to the farmer (Tables 12 and 13).

It can be seen that the lightest class of bug damage exhibited to farmers did not exceed 15% necrotic tissue, whereas the higher classes cover the range of damage from 30% necrosis up to 100% (Table 12). In Figure 3 the means of the different seed damage classes offered to farmers are shown against the percentage of farmers considering such damaged seed as valueless. It appears that 22% of farmers would regard seed damage levels of 30% as a total loss, whereas by the time seed damage reaches 50% of the seed, 50% of farmers consider the seed to be valueless. At 80% seed destruction, all farmers consider the seed to be a total loss.

In the seed damage survey reported here, as in previous surveys by Minja (1997), any damage to a seed is considered to involve the loss of that seed. The implication of farmers' evaluations of seed loss is that with a balanced spread of damage classes within the overall population of damaged seeds, researchers are probably exaggerating true yield loss levels experienced by farmers by up to two times, although this does not allow for the considerable loss of quality and flexibility of use (e.g. seed not plantable) which the farmers suffer in accepting damaged seed.

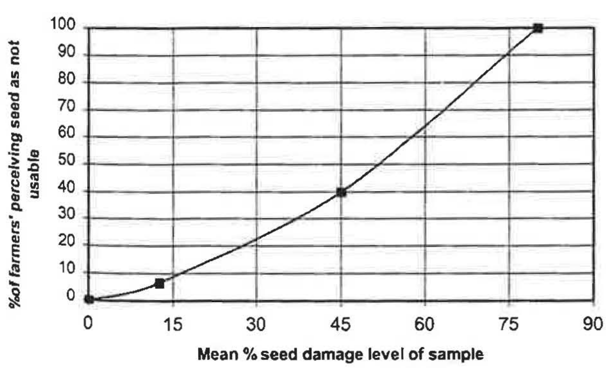

Figure 3. Farmers' perceptions of loss of value from seed classes with increasing mean percentage damage levels.

Table 13. Farmers' perceptions of seed damage from pod-boring caterpillars

Farmers' perception	Damage Slight*		Medium†		Serious‡	
	No.	%	No.	%	No.	%
Usable	12	80	11	73.33	2	13.33
Useless	3	20	4	26.67	13	86.67
Total	15	100	15	100	15	100

*Slight damage (<30% seed volume consumed).
†Medium damage (31–60% seed volume consumed).
‡Serious damage (>60% seed volume consumed).

Farmers are more tolerant of seeds which have been partly eaten by pod borers than they are of bug-sucked seeds (Table 13). Seeds which have lost up to 60% of their mass are still considered usable by 73% of farmers, although at higher levels of damage acceptability drops to 13%. However, in reality, seeds which have been partially consumed by borers are quite rare in pigeonpea since the caterpillar usually consumes the whole seed before ceasing feeding. Probably 80–85% of seeds damaged by borers are totally destroyed. It follows, therefore, that borer damage is probably less exaggerated by researchers than bug damage. An assumed inflation of about 1.2 is probably adequate to ensure that damage to pods is conservatively valued for purposes of economic analysis.

It should be borne in mind that early damage by sucking bugs results in a pod with fewer apparent seeds, such that the cause of the vanished seed is often not recognized. In the case of pod borer damage, seed loss begins in the flowering stage with the destruction of the young ovary by the same borers, e.g. *Maruca vitrata* (Shanower *et al.*, 1997) which go on to feed within the developing pods. The only way to estimate such losses is to conduct exclusion experiments comparing plants sprayed at flowering with unsprayed controls. In the FSIPM Project trials, farmers often complained of flower fall, which they usually attribute to wind, though it is almost certainly largely caused by pests. Some varieties (e.g. Chilinga) can produce a second batch of flowers to replace those lost to insects and this characteristic is much valued by farmers. The total impact of insect pests on seed yield is, therefore, likely to be under-estimated by researchers, though establishing the true figure may be difficult and probably prohibitively expensive.

Results of preliminary survey of pod pests

The species of Hemiptera observed attacking grain legumes in Blantyre/Shire Highlands are summarized in Table 14 and illustrated in Plate 2. At least seven species belonging to five families have been observed feeding on pigeonpea, of which the Coreidae are the most important. *Clavigralla tomentosicollis* appears to be the commonest species found on pigeonpea pods. Pod-sucking bugs are able to feed on plant shoots as well as pods

Table 14. Pod-sucking bugs (Heteroptera) found on grain legumes in Blantyre/Shire Highlands

Species	Description	Pigeon-pea	Soya-bean	Bean	Cow-pea	*Tephrosia*	*Crotalaria*	*Sesbania*
Clavigralla tomentosicollis Stål (Coreidae)	Broad brown spiny bug	Yes		Yes	Yes			
Clavigralla elongata Signoret (Coreidae)	Elongated brown spiny bug	Yes		Yes	Yes			
Anoplocnemis curvipes F. (Coreidae)	Large blackish bug with large legs	Yes		Yes	Yes	Yes	Yes	
Riptortus dentipes (F.) (Alydidae)	Elongated bug with white lateral longitudinal bands	Yes			Yes	Yes		
Nezara viridula (L.) (Green stink bug) (Pentatomidae)	Green shield bug	Yes		Yes		Yes		Yes
Calidea sp. (Blue bug) (Scutelleridae)	Large irridescent blue bug	Yes						
Helopeltis schoutedeni (Mosquito bug) (Miridae)	Slender reddish bug	Yes	Yes			Yes		

and are apparently polyphagous on a range of legumes. This enables successive generations to feed on bean, *Tephrosia* and pigeonpea as they become available.

The results of the rearing programme for lepidopterous pod borers are summarized in Tables 15 and 16 by legume hosts and localities, respectively.

Two surprising results of this survey were the detection of high numbers of the noctuid *Pardasena virgulana* (Plate 2) and the tortricid *Leguminivora ptychora* (Plate 2). *Pardasena virgulana* appears not to have been recorded on pigeonpea previously from Malawi, but is recorded from Kenya and Mauritius (Zhang, 1994). The abundance of this species certainly merits further study, as published records of other species may actually be misidentifications of *P. virgulana*. The early instar larvae differ greatly in their appearance from later larvae (Plate 2), initially giving the impression that two distinct species were present. *Pardasena virgulana* was occasionally parasitized by a *Cotesia* sp. (Hymenoptera: Braconidae). *Leguminivora ptychora* is a well-documented

Table 15. Pod-boring Lepidoptera reared from legumes in Blantyre/Shire Highlands (August–September 1999) with relative frequency indicated

Pod borer species	Description of larva	Pigeonpea (*Cajanus cajan*)	Fish bean (*Tephrosia vogelii*)	Sun hemp (*Crotalaria ochroleuca*)	Lablab bean (*Dolichos lablab*)
Helicoverpa armigera Hübner (Noctuidae)	Variable – green, brown or reddish stripes. Later instars much larger than other species.	1111		1	1
Pardasena virgulana Mabille (Noctuidae) (Plate 2)	Green/cream stripes in early instars; distinctive dorsal chevron pattern in later instars.	11111111			
Maruca vitrata F.) (Pyralidae) (Plate 2)	Pale green with four rows of dark brown spots.	11		11	1
Etiella zinckenella Treitschke (Pyralidae)	Yellow-cream without spots but can be more pinkish-purplish (so could be confused with *L. ptychora*).	1	11	1	
Leguminivora ptychora Meyrick (Tortricidae) (Plate 2)	Bright red.	11111111111	1		
Tortrix dinota Meyrick (Tortricidae)	Green with chocolate stripes	1			1
Exelastis atomosa Walsingham (Pterophoridae)	Dull purplish-brown with rows of small paler and darker spots. Very long setae (Plate 2).	11111			
Lampides boeticus L. (Lycaenidae)	Slug-like.	1		111111111111	
Lycaenid sp. *B*	Slug-like. Small adult with speckled underwings.			11	
Lycaenid sp. *C*	Slug-like. Large adult.			1	

Plate 1. Pod-sucking bugs: 1. *Callidea* sp. (Scutelleridae); 2. *Riptortus dentipes* F. (Alydidae); 3. *Nezara viridula* (L.) (Pentatomidae); 4. *Helopeltis schoutedeni* Reuter (Miridae); 5. *Anoplocnemis curvipes* (F.) (Coreidae); 6. *Clavigralla elongata* Signoret (Coreidae).

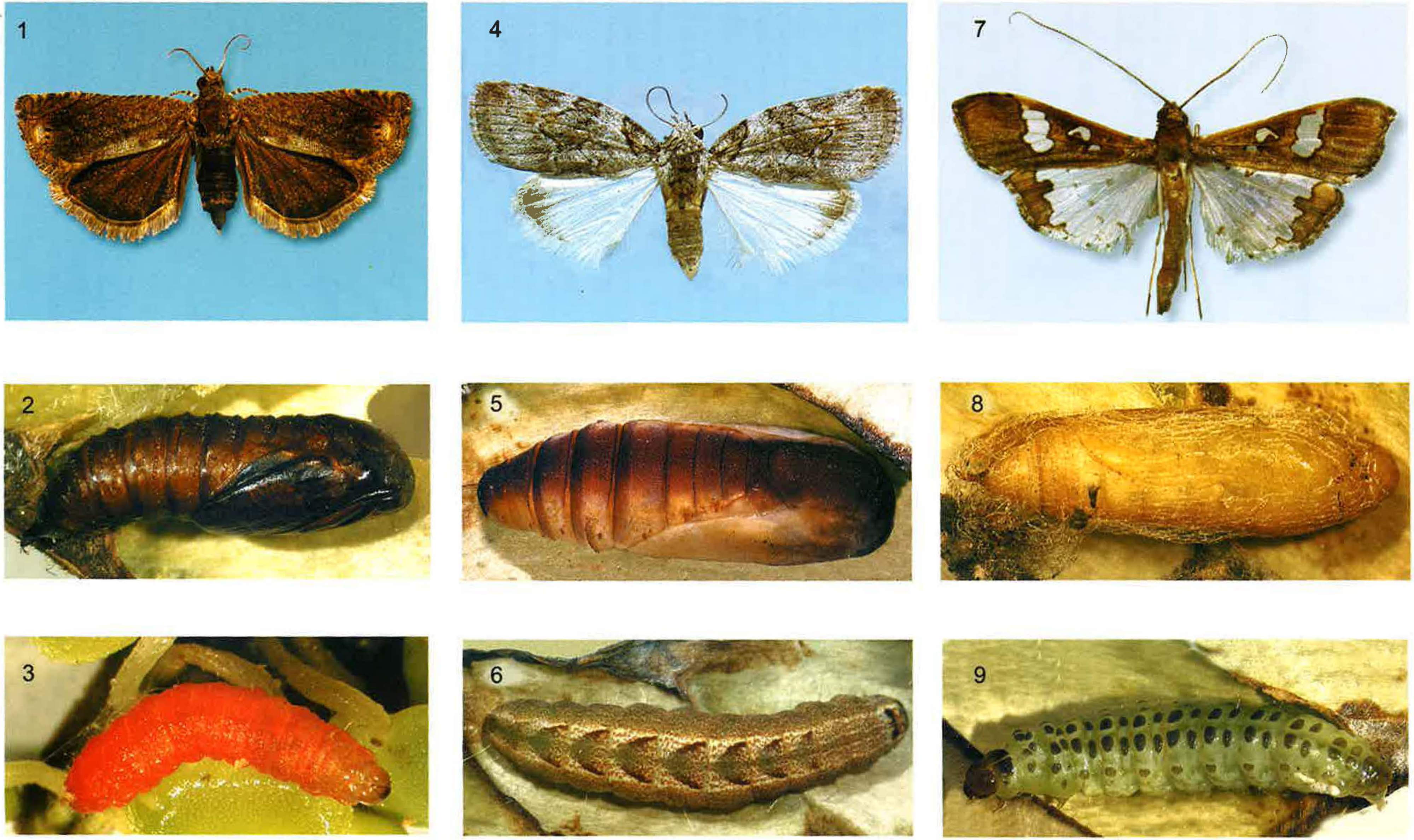

Plate 2. Pod-boring Lepidoptera: 1–3 *Leguminivora ptychora* (Meyrick) (Tortricidae) adult, pupa and larva; 4–6 *Pardasena virgulana* (Mabille) (Noctuidae) adult, pupa and late instar larva; 7–9 Maruca vitrata (F.) (Pyralidae) adult, pupa and larva.

Table 16. Distribution and relative frequency of occurrence of pod borer species attacking legumes at FSIPM Project field sites (August–September 1999)

	Section		
Species	Lirangwe	Nansadi	Mangunda
Helicoverpa armigera (Noctuidae)	11		1111
Pardasena virgulana (Noctuidae)	1	1	11111111 1
Maruca vitrata (Pyralidae)		1	1111
Exelastis atomosa (Pterophoridae)			1111
Leguminivora ptychora (Tortricidae)		1111	111
Tortrix dinota (Tortricidae)			111
Lampides boeticus (Lycaenidae)	1		11111111 1111
Lycaenidae sp. *B*			1
Lycaenidae sp. *C*			1

pest of legumes in Africa and Asia (Zhang, 1994), but had not been hitherto identified from the study area as a pest of pigeonpea.

The African bollworm, *Helicoverpa armigera*, is under-represented in the sampling reported here because it feeds largely externally in the later instars and so is not easily collected with pods, being able to drop to the ground when the bush is disturbed. Mainly large larvae were found and it is likely that most of the population had already pupated before the survey. There was evidence of *H. armigera* feeding damage from the high numbers of large holes found in pods, which indicated that this species is in reality very common, if not the commonest borer species.

Within pods of both pigeonpea and *Crotalaria*, a large species of chalcidoid wasp, *Eurytoma* sp., was also abundant. *Eurytoma* spp. have varied biologies, and elsewhere during the survey other *Eurytoma* spp. were collected, at least one of which is a hyperparasitoid of Braconidae.

Data on the natural enemies collected during the survey will be reported in detail elsewhere (Polaszek, in preparation). The blue butterfly, *Lampides boeticus*, was heavily parasitized by *Neotypus intermedius* (Hymenoptera: Ichneumonidae), especially on *Crotalaria* where 50% parasitism was encountered. *Maruca vitrata* was also parasitized more heavily on *Crotalaria* than on pigeonpea, in this case by a *Braunsia* sp. (Hymenoptera: Braconidae). The pigeonpea defoliator *Orgyia ?mixta* (Lymantriidae) was extremely common, but was found to be almost 100% parasitized, apparently in all cases by *Glyptapanteles africanus* (Cameron).

The higher incidence of borer parasitoids in non-crop hosts has been noted previously in wild grasses adjacent to maize or sorghum fields (Polaszek and Khan, 1998). Further studies (currently in progress) on the relations between pod borers, their crop and non-crop hosts, and their natural enemies, may well have implications for the development of IPM programmes, as was shown recently for cereals (Khan *et al.*, 1997). The chemistry behind these tritrophic interactions also needs to be investigated for leguminous crops. The present preliminary survey has only touched on parasitoids or other natural enemies, and hence specific opportunities for either classical biological control or augmentation have yet to be identified. Shanower *et al.* (1999) reviewed in detail several options for classical biological control of legume pests. Specifically, their suggestions for using egg-parasitoids of pod-sucking bugs and *H. armigera* deserve further investigation. One problem with pigeonpea that these authors have stressed is the presence of long trichomes and sticky exudates on pigeonpea pods which interfere with parasitoid searching ability while encouraging borers (Shanower *et al.*, 1999). This may, at least in part, explain the greater levels of parasitism on non-crop legumes encountered during the current survey.

DISCUSSION AND CONCLUSIONS

Medium duration (intercropped) varieties at Mangunda

Study of the performance of medium duration varieties ICP 6927, ICEAP 00073, ICEAP 00068 and Chilinga in a trial at Mangunda showed that Chilinga had greatest resistance to damage by pod pests. However, there was clear evidence of Chilinga's superiority only with respect to the percentage of pods with external damage ($P<0.001$). The odds of external damage with ICEAP 00073 were about twice that for Chilinga, while for ICEAP 00068 and ICP 6927, the odds of damage were over seven times higher compared to Chilinga.

Odds of damage by pod flies were again higher for varieties ICEAP 00068, ICEAP 00073 and ICP 6927 compared to Chilinga. The odds ratios for the ICEAP varieties relative to Chilinga were about 3 while for ICP 6927, the odds ratio was about 6. The differences were, however, not significant ($P=0.333$), probably due to high variation in the damaged proportions between plots.

With respect to damage by pod borers, there was some indication that varieties Chilinga and ICEAP 00073 had greater resistance than varieties ICEAP 00068 and ICP 6927.

Long duration (sole or intercropped) varieties at Mangunda

Long duration varieties ICP 9145, ICEAP 00040 and ICEAP 00053 were grown as sole crops and also as intercrops with maize. The analysis did not demonstrate any significant differences in pod pest damage across varieties, or between cropping patterns (sole/intercrop). There was also insufficient evidence of a cropping pattern by variety interaction.

However, results of the analysis showed greater resistance to external pod damage by variety ICP 9145 than the ICEAP varieties when all varieties were grown intercropped with maize. Visible external damage for ICP

9145 was significantly lower by about 60% than that for ICEAP 00053 (P=0.032) when these varieties are intercropped. ICP 9145 also appeared to have an advantage over ICEAP 00040 (50% reduction in external pod damage) but this reduction was non-significant. The non-significance is likely to be due to high plot-to-plot variability under on-farm conditions.

ICP 9145 did not demonstrate an advantage over the ICEAP varieties under sole cropping.

Long duration (intercropped) varieties in main intercrop trial

A pod pests survey was also carried out within the main intercrop trial in Chiradzulu and Matapwata where varieties ICEAP 00053, ICEAP 00040, ICP 9145 and a local variety were grown intercropped with maize and bean. The data analysis demonstrated that pod damage was much higher in Matapwata than in Chiradzulu, the odds of overall damage being about twice as high in Matapwata compared to Chiradzulu. The odds ratios were highest for pod flies, with odds of damage about five times higher in Matapwata relative to Chiradzulu.

Varietal comparisons demonstrated that the local variety had greatest resistance to pod pests followed by variety ICP 9145. The differences were significant (P<0.001) with respect to overall damage and damage caused by pod-sucking bugs. For all varieties, damage by pod flies was very low (<2%) but there was some evidence of variety differences due to pod flies (P=0.046). Again the local variety showed the least damage.

Promising varieties

Of the four medium duration varieties, Chilinga was clearly the most promising variety with respect to overall pod pest resistance. There was generally little difference between the two ICEAP varieties, but ICEAP 00073 had considerably less visible external damage and less damage by pod borers than ICEAP 00068. The most susceptible medium duration variety to pod pests was ICP 6927.

Under sole cropping in the Mangunda trial, ICEAP 00040 had lower pod borer attack and lower external damage to pods compared with ICEAP 00053 and ICP 9145. This type of damage was, however, lower than damage caused to seed by pod-sucking bugs. All varieties had more than 40% of seeds damaged by sucking bugs, with attack on ICP 9145 being about 20% lower compared to the other two varieties.

In the Mangunda trial under intercropping, the percentage attack by pod-sucking bugs was slightly lower (38–49%). The attack was even lower in the main intercrop trial with attack levels ranging from 11% to 20% in Chiradzulu and 14% to 30% in Matapwata (Table 17). In the main intercrop trial, a local variety was also grown and had an even lower attack of about 12%.

Pod fly attack was extremely low under both sole cropping and intercropping for all varieties.

Table 17. Predicted percentages of seeds damaged by pod sucking bugs under intercopping conditions in the main intercrop trial and at Mangunda

	Predicted seeds damaged (%)		
Variety	**Chiradzulu**	**Matapwata**	**Mangunda**
Local	10.8	13.6	-
ICEAP 00053	13.6	20.3	44.5
ICEAP 00040	20.2	30.3	48.9
ICP 9145	13.7	17.2	37.6

Table 18. Predicted percentages of seeds damaged by pod borers under intercopping conditions in the main intercrop trial and at Mangunda

	Predicted seeds damaged (%)		
Variety	**Chiradzulu**	**Matapwata**	**Mangunda**
Local	4.2	7.0	-
ICEAP 00053	3.6	11.1	10.8
ICEAP 00040	2.6	9.0	7.1
ICP 9145	2.0	9.7	5.3

Visible external damage and seed damage by pod borers under intercropping was lowest for ICP 9145 followed by ICEAP 00040 and ICEAP 00053 in the trial at Mangunda where intercropping was with maize alone. Results were similar in the main trial at Chiradzulu and Matapwata under intercropping with both maize and bean. However, there was considerable variation in the overall percentage of seeds attacked by pod borers between the three areas (Table 18). Chiradzulu had lowest attack (2–4%) while at Matapwata and Mangunda, the percentage damage was 7–11% and 5–11%, respectively. This variation is believed to be due to different levels of pest populations at the different locations, possibly mediated by climatic differences.

Overall, the local variety and variety ICP 9145 appear to be the most resistant to pod pests. There is little to choose between ICEAP 00053 and ICEAP 00040. The former appears to be more resistant to pod-sucking bugs, while ICEAP 00040 seems to have a slight advantage over ICEAP 00053 with respect to attack by pod borers.

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DISCUSSION

E. Minja. This is the first set of results on arthropod pest assessment in on-farm trials for the pigeonpea project in southern and eastern Africa.

The predicted levels of borer damage to pigeonpea seeds and pods is consistent with results obtained from medium duration landraces in farmers' fields in Kenya, southern Malawi, Tanzania and northern Uganda (Minja, 1997; Minja *et al.*, 1999a). However, the predicted levels of sucking bug damage on pigeonpea seeds in Malawi appears much higher than previous records where the level ranged from 4% to 17% contributing to about 70% of the total seed damage in Malawi. The predictions for pod fly incidence are in agreement with previous records. It is important to note that the incidence, distribution and damage levels due to pests on pigeonpea vary with seasons, locations and countries. ICP 6927 showed a similar high susceptibility to insect pest damage in Kenya (Minja *et al.*, 1999b).

Intercropping medium and long duration pigeonpea with maize has not shown any significant differences in pest incidence because the two crops mature at different times during the season (Reed and Lateef, 1990; Shanower *et al.*, 1999). Pest build-up on pigeonpea starts long after maize has been harvested. The interactions observed here between cropping patterns and varieties should be confirmed by larger field plots and several seasons of field trials in varying locations. There may be significant gains in land productivity if the grain yield for both crops is recorded and compared per unit of land area, but some seasons and locations may give different results on productivity as well (Minja, 1997).

EPA differences conform with the results obtained from Kenya, Malawi and Tanzania that pigeonpea incidence and severity differ with agro-ecological zones. Pod fly infestations have been associated with constantly cool weather and/or medium to high altitude locations, pod borers with warm to cool weather depending on borer species, while sucking bugs are all-weather pests on pigeonpea (Minja, 1997). Pod fly incidence and damage have been shown to be positively correlated to pod and seed sizes in that the larger the pod and seed, the higher the number and damage due to pod fly (Minja *et al.*, 1999b). It would, therefore, be expected that ICP 6927 would be more susceptible to pod fly damage. The warmer weather at Chiradzulu EPA would favour the fast hardening of pigeonpea pods that would mature faster than at Matapwata, hence there is less time for exposure to borer damage at Chiradzulu compared to Matapwata. The soils in the higher parts of Chiradzulu would drain faster than at Matapwata making plants dry up faster than in wetter areas of Matapwata. Certainly the local varieties, both medium and long duration, have adapted to the growing conditions and farmers have been selecting them for different traits over the decades. We need more entries for such trials incorporating locally selected and improved genotypes in addition to those selected at other locations.

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D. Coyne. Is an identification guide of pod pests under production/consideration?

A. P. One of the aims of the DFID-funded project is to produce diagnostic guides, based largely on illustrations, to the major lepidopteran pod borers pantropically.

F. Simtowe. Pigeonpea is a very important crop but what proportion of land does it occupy in the smallholder farming system in the study area?

A. Orr. The allocation of land to pigeonpea by smallholders for our research sites can be found in the project's baseline survey (1996/97 survey).

Modelling the impact of integrated pest management at farm level

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ABSTRACT

Whole farm models were developed to quantify the economic benefits of integrated pest management (IPM) strategies for maize, bean, pigeonpea and sweet potato on smallholder farms in Blantyre/Shire Highlands Rural Development Project (RDP), southern Malawi. Major pests and diseases included termites, *Striga asiatica* and whitegrubs in maize, stem maggot (*Ophiomyia* spp.) and *Ootheca* in bean, *Fusarium* wilt in pigeonpea and *Cylas puncticollis* in sweet potato. IPM strategies included varietal resistance in bean and pigeonpea, cultural methods for sweet potato weevil (crack sealing in ridges) and maize (not banking for termite management), seed dressing for whitegrub in maize, and trap cropping with *Tephrosia* for *Striga* control. Modelling suggests that IPM interventions increased net benefits by 31% over existing levels. IPM interventions with the greatest potential included crack sealing in sweet potato, the pigeonpea variety ICEAP 00040, no banking for termite management and seed dressing with Gaucho for controlling whitegrub in maize.

INTRODUCTION

Crop losses due to pests and diseases are still a major constraint to increased agriculture production and productivity amongst smallholder farmers in Malawi. Integrated pest management (IPM) had been widely endorsed by scientists, aid donors and governments as a pest management strategy. It is an approach that uses a variety of biological, cultural, genetic and chemical techniques to maintain pest populations below an economic damaging level. In Malawi, the development and promotion of IPM techniques in farming systems remains a high priority for government (MoAI, 1995).

However, while IPM has been successful against pest epidemics, evidence from other studies show that its effectiveness against pests of staple food crops is problematic (Orr *et al.*, 1999). On the supply side, although a wide range of potential interventions has been identified, there is a general lack of proven, effective control technologies (Kiss and Meerman, 1991). On the demand side, adoption by small farmers is limited where pests are perceived as not necessarily the most important constraint or the benefits are not high enough to compensate for the investment in that particular innovation.

What economic benefits can IPM offer to smallholder farmers in Malawi? Whole farm modelling offers one method of estimating the benefits of IPM interventions for smallholder farming systems. This approach has been widely used for *ex ante* analysis of interventions although over-sophistication has, at times, limited the usefulness of farm modelling since interactions between system components are harder to identify in complex models. This paper describes a descriptive, non-optimizing model which simplifies data analysis and where outputs can facilitate farmer-researcher dialogue in evaluating IPM interventions.

The major objective of the paper is to measure the economic impact of IPM strategies for staple food crops grown by smallholder farmers in Blantyre/Shire Highlands Rural Development Project (RDP), specifically:

- modelling the economic impact of IPM interventions for maize, bean, sweet potato and pigeonpea;
- comparing net benefits from the IPM interventions.

The key for such an analysis is to understand the relationship of any single IPM intervention to the whole farm system, taking into account farm resource constraints, current enterprises and their resource requirements.

THE PROJECT AREA AND TARGET PESTS

The Farming Systems Integrated Pest Management (FSIPM) Project has been operating in the Blantyre/Shire Highlands RDP for the past 3 years. The maize ecology in the RDP is representative of 40% of the total area planted to maize in Malawi. For the past 8 years, official estimates show maize yields averaged 836 kg/ha for local varieties and 1765 kg/ha for hybrid semi-flint varieties. Of the holdings, 60% are under 0.5 ha. Female-headed households comprise 38% of the households in the RDP (GoM, 1996). Pigeonpea and bean are the main intercrops. Relay planting of bean is a common practice but has been declining in recent years due to: (i) recent changes in weather pattern, characterized by droughts and/or frequent dry spells and early cessation, and (ii) the substitution of sweet potato and field pea which have become important components of household food and income security strategies (Mwale *et al.*, 1999).

The target pests of food crops in the RDP were identified through surveys between 1990 and 1992 and the results showed that termites, whitegrubs, *Striga asiatica*, bean stem maggot (*Ophiomyia* spp.) and *Ootheca* sp. as major pests of bean. *Fusarium* wilt was identified as the major disease of

Table 1. Estimated value of losses to food crops from pests and diseases in Blantyre/Shire Highlands RDP

Pest	Crop	Incidence[a]	Damage level[b]	Total crop loss (t)	Total production (t)[c]	Total production (t maize equivalents)	Volume of crop losses (t maize equivalents)	Price (MK/t)[d]	Value of crop losses (000 MK)	Value of crop losses (%)
Whitegrubs	Maize	21	0.13+	117	90278	90278	117	4500	527	0.5
Termites	Maize	40	2.33+	2103	90278	90278	2103	4500	9464	9.5
Striga asiatica	Maize	8 (severe)	93#	6728	90278	90278	6728	4500	30276	30.3
Weeds	Maize	36	15#	5198	90278	90278	5198	4500	23391	23.4
Bean pest and disease complex:	Bean									
Ootheca		61	–	–	2576	2389	60	16000	1040	1.0
Bean stem maggot		9	0.3+	8						
Alcidodes		46	1.3+	34						
Stem/root rot		34	0.9+	23						
Pod borers, pod suckers, pod flies	Pigeon-pea	100	10.5#	862	8205	7348	772	6500	5603	5.6
Fusarium wilt	Pigeon-pea	16	22#	1805	8205	7348	1617	6500	11733	11.7
Cylas puncticollis	Sweet potato	100	15#	6005	40032	12610	1892	3000	18015	18.0
Total				17685	141091	112625	18487		100049	100.0

Note: + = % of plants killed; # = % of yield lost.

Source: unless stated all references are to Abayesekera (1999). Data on incidence and damage level are for 1997/98 except for *Cylas* and pod borers, which are for 1998/99.

[a]Plots attacked: whitegrubs, 2–16 Table 25; termites, 2–22; *Striga*, area severely infested (Chanika and Koloko, 1998); weeds, 36 % of area planted not banked within 6 weeks of planting (Orr *et al.*, 1998); *Otheca*, 3–7 Table 14, others 3–12 Table 24; pod borers, pod suckers and podflies, (J. M. Ritchie, pers. comm.; *Fusarium*, 4-8 Table 13).

[b]Plant deaths: whitegrubs, 2–17 Table 28; termites (lodged plants) 2–20 Table 35; *Striga*, 140 emerged *Striga* plants/m^2, giving a yield loss of 1520 kg/ha; bean stem maggot, 3–17 Table 37; *Alcidodes*, 3–21 Table 45; stem/root rot, 3–14 Table 28; pod borers, pod suckers and podflies, 17.3 % (researcher estimate) adjusted to 10.5 % (farmers' estimated damage); *Fusarium*, 4-19 Table 26; sweet potato (Mombezi upland), farmers' damage level.

[c]Blantyre ADD Third Crop Estimates, 1998/99.

pigeonpea (Munthali *et al.*, 1993). These rankings were confirmed by a Stakeholder Workshop of Malawian crop protection professionals and by diagnostic surveys using participatory techniques in four villages in Mombezi and Matapwata Extension Planning Areas (EPAs). Sweet potato weevil (*Cylas puncticollis*) is also a major constraint to smallholder sweet potato production. Field crop losses from these pests in the RDP have recently been estimated at 15% of the total value of crop production. This ranges from 1% to 30% (Table 1).

DATA AND METHODS

Cluster analysis was used to identify representative farm households for modelling (Orr and Jere, 1998). IPM strategies are more likely to be adopted if they are combined with clear identification of target groups. Data for cluster analysis derived from a baseline survey of 120 households conducted at the FSIPM Project sites in four villages in two EPAs during the 1996/97 crop year (Orr *et al.*, 1997). The sample was stratified by EPA, by participation in on-farm trials, and by sex of household head. The results showed that smallholders in the project area could be stratified into five broad groups:

- *dimba* households (one third of which were female-headed households) producing maize and vegetables (Cluster 1);
- stable male-headed households producing neither vegetables or burley tobacco, but producing enough maize to be reasonably food secure (Cluster 2);
- vulnerable households which produced neither vegetables nor burley tobacco, nor enough maize to be food secure (Cluster 3);
- burley households which did not produce vegetables but produced enough maize to be reasonably food secure (Cluster 4);

Table 2. IPM interventions modelled, FSIPM Project

Existing enterprises	IPM intervention
Unfertilized hybrid maize	
Unfertilized local maize	
Fertilized local maize	
Local maize with *Striga*	*Tephrosia* as trap crop
Unfertilized composite maize	
Fertilized composite maize with *Striga*	*Tephrosia*
Fertilized composite maize with termite	Not banking
Fertilized composite maize with whitegrub	Seed dressing with Gaucho-T
Beans with bean stem maggot, main intercrop	Resistant bean variety
Field pea	
New variety pigeonpea	
Pigeonpea with *Fusarium* wilt	Resistant pigeonpea variety
Sweet potato in the *dambo*	Crack sealing
Sweet potato in the upland	Crack sealing
Fertilized hybrid	
Cassava	

- stable female-headed households which produced neither vegetables nor burley tobacco, but produced enough maize to be reasonably food secure (Cluster 5).

Enterprise budgets were constructed for 16 existing agricultural activities and six IPM interventions (Table 2). Data on crop losses and crop loss reduction from IPM interventions was obtained from on-farm trials. Areas under each enterprise were derived from field measurements and yields from FSIPM trials. Data on labour requirements for enterprises were obtained from Werner (1987) and Sam (nd) plus FSIMP trial recordings, particularly for crack sealing in sweet potato. Input and output prices included those from local markets (obtained through informal surveys during marketing days) plus official ADMARC prices for the 1998/99 season for fertilizers and consumer prices. The wage rate for male estate labour in the 1998/99 season was obtained from neighbouring estates.

The IPM interventions that were modelled included:

- use of *Tephrosia* for *Striga*
- early maturing bean variety
- varietal resistance for *Fusarium* wilt for pigeonpea
- sealing of cracks on sweet potato ridges to prevent entry by the sweet potato weevil (*Cylas puncticollis*) (Pardales and Cerna, 1987)
- maize seed dressing with Gaucho-T for whitegrub
- not banking in maize field for termite control.

A new improved pigeonpea variety, ICEAP 00040, was modelled for resistance to wilt instead of IC9145 which is a variety already widely grown by smallholder farmers. ICEAP 00040 is a Kenya landrace which has been tested under the project for the past 2 years.

Interventions were modelled using the software FARMACTION (Magor, 1992). The basic building block of FARMACTION is the 'enterprise', defined as a unit of economic activity. Enterprise budgets were combined into farm plans with the mix of enterprises and level or area under each enterprise determined by baseline survey data for three of the five clusters. Two farm plans were modelled for each cluster: the existing system and changes with IPM interventions. The method is purely descriptive, without optimization subject to resource constraints. The results presented here are preliminary and subject to further validation.

RESULTS

Table 3 compares the relative impact of IPM interventions for each of the three clusters. In general, IPM interventions increased net benefits for all the clusters. On a full-cost basis, IPM interventions increased net benefits with a weighted mean of 31%.

The greatest proportionate increase were found among the stable female-headed household cluster (38%), followed by vulnerable households (35%) and the stable male-headed household (20%). IPM interventions marginally increased material cash costs. The highest change in material cash

Table 3. Gross returns, labour inputs, material costs under existing system and IPM interventions (MK/household)

Cluster	Vulnerable household	Stable male-headed household	Stable female-headed household
Gross returns			
Existing	18,854	25,475	15,551
IPM	23,243	28,787	19,110
Labour days			
Existing	117	235	145
IPM	139	247	148
Labour costs			
Existing	2691	5405	3356
IPM	3197	5681	3420
Material costs			
Existing	5051	5145	3291
IPM	5323	5171	3337
Net benefits (full-cost basis)			
Existing	10,868	14,922	8904
IPM	14,730	17,923	12,352
% change net benefits	35	20	38

Source: FARMACTION printouts, November 1999.

costs was found in vulnerable households (MK272/year) while in other households it was less than MK50.00. Labour requirements resulting from IPM interventions were increased on average by 12 days/year. The highest change in labour input was found with vulnerable households (22 days/year), followed by the stable male-headed household group (12 days) and the least was the stable female-headed household group with an increase in labour requirements of only 3 days/year.

Table 4 shows the net benefits (gross returns minus material and labour costs) associated with each IPM intervention. Total net benefits varied from MK3106 to MK4484 per household per year. Crack sealing for sweet potato gave the highest net benefits despite high additional investment in labour costs for the stable female-headed household and stable male-headed household clusters. The vulnerable cluster got most benefits from the growing of pigeonpea variety ICEAP 00040. There was considerable variation in net benefits due to IPM interventions, *Tephrosia* trap cropping for *Striga* control, termite management, bean varietal resistance and use of Gaucho-T seed dressing. For example, the next best IPM intervention for stable male-headed households was ICEAP 00040 pigeonpea variety, with net benefits of MK614 while for stable female-headed household it was the use of Gaucho-T with net benefits of MK668.

DISCUSSION

An understanding of the relationship of any single innovation to the *whole farm* is the key to overall evaluation of IPM. Thinking in terms of a 'farm' encourages a more dynamic perspective. Clearly, IPM strategies for major food crops have some potential to raise income and improve sustainable livelihoods in southern Malawi, particularly among resource-poor households. With an overall mean increase in net benefits of 31%, smallholder farmers should expect to gain, on average, if they adopt IPM interventions. On a single IPM intervention case by case basis, the results showed that some IPM technologies were more promising than other technologies.

The individual interventions that showed consistently good performances across the three clusters included:

- crack sealing in sweet potato
- ICEAOP 00040 pigeonpea variety
- seed dressing with Gaucho-T for whitegrub in upland maize
- trap cropping *Tephrosia* for *Striga* control.

Table 4 Estimated net benefits from IMP interventions by cluster groupings (MK/household) 1998/99 prices

Cluster group	Vulnerable household	Stable male-headed household	Stable female-headed household
IPM interventions			
Sweet potato crack sealing	***1190***	**1808**	**1190**
Early maturing variety (Kaulesi – main crop)	**140**	***133***	79
Maize seed dressing with Gaucho-T	392	370	***668***
IPM termite control (not banking)	1142	486	341
Composite with *Tephrosia* for *Striga* control	-95	614	470
ICEAP 00040 pigeonpea variety	**1492**	***1073***	358
Total	**3233**	**4484**	**3106**

Source: FARMACTION printouts.

All the food crops discussed here have come to play an increasingly important role in the farming systems of southern Malawi. For instance, official statistics show a nine-fold increase in the production of sweet potato in Malawi during 1993/94–1997/98, when average yields doubled from 5 t to 10 t/ha (FEWS, 1998). This expansion is a result of an increase in planted area resulting from substitution of sweet potato for other crops and increases in yield through the adoption of the high yielding Kenya variety. Given the high losses from sweet potato weevil (20–30%), an IPM strategy which uses cultural rather than chemical control offers poor households an affordable method of improving food security.

However, the benefits from this analysis are shown to be higher than those obtained from the 1997/98 whole farm models because of substantial changes in the input and output prices. For instance, a maize consumer price of MK8.50 represents more than 100% increase in the maize producer price of 1997/98 season. In FARMACTION the input and output prices can be adjusted depending on the prevailing economic conditions at any particular time.

CONCLUSION

Whole farm modelling suggests that IPM offers some scope for reducing poverty and improving livelihoods of smallholder farmers in southern Malawi. Six interventions targeted at major pests of maize, bean, sweet potato and pigeonpea resulted in an average 31% increase in net benefits over existing levels.

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DISCUSSION

F. M. T. Gondwe. Modelling shows that the FSIMP Project has benefited the farmer an equivalent of 31%. How does this marry with earlier presentations which stated that some IPM interventions were not very successful?

B. M. This is the overall impact of IPM. While some IPM interventions have less impact (e.g. trap cropping for *Striga* control), other IPM interventions have had more effect (e.g. crack sealing for sweet potato). Modelling relates single interventions to others on the farm as a whole.

D. Coyne. From where is the estimated crop loss due to pest and diseases derived?

B. M. Refer to Table 1 – the project's own estimations based on trial results and farmers' perceptions of damage by different pests.

K. M. Chavula. Although I do not have quantified information I doubt that the Blantyre/Shire Highlands RDP represents 40% of the area planted to maize. The ecology of the area is similar to Tsangano, Dedza, Vipya and Ngaka which are not important maize areas.

B. M. The information came from secondary sources, i.e. GIS at Chitedze.

B. Msiska. The percentages in Table 3 add up to 93%. What does the remaining 7% represent?

B. M. The percentages cannot add up to 100% because each model for each household is run separately.

B. Msiska. Is it not surprising that the vulnerable households have an overall total benefit higher than the stable female-headed households and yet the vulnerable had -95 benefits under 'composite with *Tephrosia* for *Striga* control'? Does this mean that the vulnerable households in this case are more economically secure than the stable female-headed households?

B. M. The overall net benefit is simply the sum of the individual net benefits of each IPM intervention. While vulnerable households have -95 net benefits from the *Striga* intervention they had MK1142 net benefits from the IPM termite intervention opposed to MK341 for the female-headed households. Again remember we are looking at overall impact not single IPM technology case by case. Again this is potential benefits.

3. The Researcher–Farmer Interface in Integrated Crop Management

KEYNOTE ADDRESS

Managing the researcher–farmer interface in on-farm experimentation: issues and challenges for integrated crop management research

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ABSTRACT

Agricultural researchers have, over the past two decades, come under increasing pressure to consult with farmers and involve them as partners in the research process. This has been in response to the perceived poor performance of linear transfer of technology approaches in producing technologies that have been adopted by small-scale farmers. To set the context, this paper looks at three type of preconditions for effective participation by farmers in researchers' activities: preconditions relating to researchers, to farmers, and some general ones. Key issues that arise at the researcher–farmer interface are then discussed, including addressing suspicions and building trust; promoting knowledge exchange and sharing its ownership; developing language and communication skills; acknowledging differences in goals; managing incentives; enhancing skills and capacity building; managing varying time-scales; acknowledging power relations; sensitivity to gender roles and cultural etiquette; and the hazards and benefits of working through intermediaries. In discussing these issues the paper draws upon examples and experience from on-farm research into integrated crop management-related issues in Kenya, Zambia, Malawi and other countries. Key challenges that lie ahead of researchers and funding agencies, whose goal is to work more effectively with farmers on integrated crop management research issues, are signalled. Three challenging areas identified relate to research methodology, continuity over time in farmer–researcher and researcher–researcher relations, and operational linkages to achieve impact from research through agribusiness support initiatives (input supply, credit and markets).

INTRODUCTION

Should there need to be a research–farmer interface to manage? What is wrong with researchers conducting experiments on research stations and handing over the results to extension agencies to disseminate to farmers? Isn't all this talk of farmer participation part of a donor fad or fashion?

These questions may be valid coming from a policy-maker, or from a research scientist who has never ventured off the research station. Yet most agricultural researchers in Africa and other parts of the developing world would not ask such questions today. They are familiar with cases where years have been spent developing technology that has either not been adopted by smallholder farmers at all, or has been taken up by only a few farmers. Those researchers who have undertaken researcher-managed on-farm trials will also know the challenges of experimental management, data collection and data analysis under on-farm conditions, and the potential pitfalls and limits of farmer participation (Pjinenberg, 1998). Some of these researchers will admit they had to change their ideas and approach to research after they had involved farmers in the process of experimentation.

When farming systems research approaches were introduced to Africa in the 1980s, the focus was primarily on maize (Low *et al.*, 1991). In many cases, surveys showed that farmers were not following the technical recommendations developed by research. By involving farmers in this research, and finding out their reasons for not adopting all of the recommendations, research was initiated that resulted in more appropriate products and management recommendations for the production of maize under varied ecological and socio-economic circumstances. For example in Malawi, research into the production of flint-type maize hybrids was largely in response to farmers' preferences during the 1980s for growing local flint varieties for home consumption and hybrids for sale. The production of flint hybrids is not the end of the story. Green revolution-type high-input technologies had a brief honeymoon period in the small-scale sector in some African countries through hybrid maize fertilizer packages provided on credit. However these technologies, being targeted at producing cheap food for urban areas, had very limited impact on poorer farmers unable to access the inputs, or on farmers living in remoter areas with poor access to markets. Economic liberalization and structural adjustment have questioned the sustainability of higher-input technologies developed by research systems. For example, hybrid maize and fertilizer use by small-scale farmers has declined considerably since the removal of supportive subsidies and credit programmes. Farmers are complaining of the high prices of hybrid seed and fertilizer. The need for more sustainable technologies that can produce a surplus of food and cash crops with fewer and more affordable external inputs is increasingly being recognized. There is growing interest from smallholder farmers in lower-input methods for maintaining soil fertility and controlling pests and diseases.

Concerns about pesticide resistance, health and safety related to pesticide use, and environmentally sustainable agriculture have lent support to the concept of integrated crop management (ICM). ICM captures the trend in applied agricultural research to enlarge the scope of integrated pest management (IPM), to include other issues relating to crop management, particularly plant health and soil fertility. It is an appropriate term to describe the evolution of the research programme of the Farming Systems Integrated Pest Management (FSIPM) Project. The FSIPM Project investigated pest management issues within a farming systems context, and through interaction with farmers discovered that soil fertility was regarded by farmers as a more important problem than pests, and also that soil fertility was related to the severity of losses caused by pests and diseases in some crops (Orr, 1997).

ICM implies that researchers too should be 'integrated'. Different disciplines including entomology, plant pathology, soil science, microbiology, plant breeding, agronomy and social sciences need not work in isolation. The management world has recognized for a long time that complex problems are best tackled by teams with a range of expertise (Tidd *et al.*, 1997). Agricultural research which has ICM and natural resource management objectives implies the need for an interdisciplinary approach. This does not mean that ICM will be a band-wagon that all researchers should try and jump on, but that it might provide a useful framework within which to develop strategic working partnerships between disciplines in tackling the problems faced by small-scale farmers.

Experience has shown that developing interdisciplinary working partnerships is not an easy task (Leibler, 1994). It is relatively easy to bundle a range of disciplines together under the label 'multi-disciplinarity'. Yet, the tendency in many multi-disciplinary teams is for each researcher to go off in their own direction; each has their own budget and experimental programme. Things can change when such a team comes face-to-face with farmers asking difficult questions. There is an immediate need for researchers to think far beyond their own discipline. Farmers may ask specialist scientists questions which require them to consult with colleagues.

Farmer participation therefore provides a valuable focal point for interdisciplinary research, which allows researchers to work more effectively together to tackle a common problem. Farmers' local knowledge can be combined with that of researchers in order to speed up the diagnosis of problems and search for a wider range of solutions. One precondition for effective interdisciplinary research is an enabling organizational environment, in which researchers are encouraged to address cross-cutting issues and budgets are allocated for this.

Farmer participation also facilitates the involvement of a wider range of other stakeholders, so that the impact and uptake of research will improve. Farmers will not be satisfied to see just that a new technology works, they will be equally concerned to find out how they can access this technology on a sustainable basis, and how they can dispose of the increased value added (e.g. higher production, new crop, labour saved, more refined agricultural product). If such concerns are to be addressed by researchers, strategic links with agribusiness, extension and finance institutions will need to be established. With the growth of outgrower schemes and contract farming in the central Africa region it is likely that agricultural researchers may be approached by the companies involved in order to tackle some of the production problems and opportunities faced.

A broad question that has to be addressed is "what is the aim of conducting ICM with farmers?" Is the aim to develop new and more productive crop management systems or optimal production packages? Or is the aim to explore various promising technical options, perhaps in association with organizational issues, to address identified problems or opportunities? The second objective is likely to be more achievable, particularly within the current context of more a more liberalized and organizationally pluralistic environment for smallholder agriculture. Farmers may accept the first approach only if large financial incentives are provided, or if adoption is made a condition of access to inputs and/or markets. This raises challenges for ICM on-farm research, which may try to prove the benefits of using a bundle or interconnected series of new management practices. It will require researchers to be more creative, wherever possible superimposing trials upon existing 'better' and 'poorer' management practices in order to demonstrate the effectiveness of an integrated approach. For example, the same pest control method might be tried on the same crop planted on more and less fertile patches of the same plot.

Is ICM an appropriate approach for the very poorest farmers? The complexity of the research issues arising may mean that the involvement of the poorest farmers is problematic, due to their limited resources for experimentation and the likely requirement for labour-intensive operations and/or purchased inputs.

CONDITIONS FOR EFFECTIVE FARMER PARTICIPATION

What would an ideal type of farmer participation in agricultural research look like? Biggs (1989) has presented a typology of farmer participation which describes the ideal as 'collegiate' participation, in which farmers invite researchers to come and assist them with their own research programme. This is a worthy ideal to aim for, but the practical implications need to be carefully considered, including the characteristics of the farming population and the capacity and organizational roles within national research systems (Farrington, 1998). For example, how could collegiate participation work in larger countries where farmers are in millions, mostly poor, semi-literate and without transport and have multiple problems, and researchers are one or two hundred only? In practice, would the researchers not quickly be swamped by a multitude of issues from which they would have to prioritize and select?

To begin to address this issue it may be helpful to look, on the basis of existing experience, at the type of conditions required for effective farmer participation. Three types of conditions are identified in this paper: those relating to the farmers themselves (as potential participants); those relating to researchers (seeking to work with farmers); and general conditions (in the community, country and region). For each category of conditions, helping and hindering factors are identified.

Helping conditions relating to participation by farmers

Accessibility

Participation from farmers is most effective when they live in an area accessible to and attractive to researchers. If they live in places that are very difficult to get to, or places that are unattractive for whatever reason, researchers will be unlikely to visit. Even if they visit once, they may not wish to return again.

Interest

If farmers have a strong interest in the research topic, and generally in acquiring new knowledge, they are more likely to participate effectively. It is not always that researchers will be willing to collaborate with farmers in any topic of research. They are specialists, and even if they are problem-oriented they will still be inclined to (and hopefully be competent in) a particular line of research. If farmers do not share this interest then they are unlikely to participate effectively. Related to this, farmers may be interested, but not knowledgeable or skilled in a particular topic. For example, farmers in semi-arid eastern Kenya were very interested in pig keeping but had no knowledge of pigs – they had only heard that domesticated pigs 'burst' if introduced into dry areas.

Relevant knowledge and time for learning

Farmers with the relevant technical knowledge and skills will be more effective participants. For example, in Zambia the farming systems team began research trials with sorghum in the hot valley areas. The agronomist and his technician were not familiar with sorghum as a crop, and in the first season they had very poor emergence and stand compared with the farmers' local sorghum. In the next season, the agronomist adopted some of the farmers' planting methods, with much greater success. In another area, farmers had been selected, based on carefully worked out socio-economic criteria, to plant a farmer-managed, researcher-designed sunflower trial. They said they were interested in sunflower. However, in most cases the crop failed because the farmers lacked experience in growing the crop, and quickly lost interest following poor emergence. If there is adequate time for learning, both by farmers and researchers, prior knowledge is a less important condition.

Other relevant resources

Farmers' ownership and access to resources, in addition to knowledge, is often very important for their effective participation. At the simplest level, how can a farmer without cattle participate in a tick control experiment? A farmer with limited land may find it difficult to participate in an improved fallow or rotation experiment. Without a plough, how can farmers be sure they can undertake a tillage operation such as plough weeding at the required time? A further aspect of this relates to the extra time required for participation in participatory agricultural research. Farmers who are resource-constrained often do not have the time to attend meetings, are often unable to commit themselves to undertaking trial management operations as agreed/requested/instructed, or simply do not want the risk or bother of an experiment on their farm. A one-off household-level assessment/inventory of resources may not be enough to assess a household's capacity to be involved in a particular experiment. It may be necessary to look more closely at who controls which resources within the household, including labour. For example, in an agro-forestry experiment in Kenya one farmer had agreed to plant trees, and explained that trees were planted by men and belonged to men. However, when it came to watering the trees he expected his wife to do it. She declined to help as she had not been consulted in the planning of the experiment, and the trees died as a result. Situations can also change over time. In another case a farmer agreed to participate in a tillage trial using ox-plough, but his oxen died so he had to drop out. In another case, a longer-term manuring experiment, there was poor communication between husband and wife, and as a result the so-called 'control' plot, intended to be without manure, had been selected by the wife on the site of an old cattle kraal.

Willingness for dialogue and risk

Farmers who are willing to engage in dialogue with outsiders are likely to be good experimenting partners. This does not, however, guarantee that they will be popular within their local community, or influential in persuading other farmers to try new ideas. For example, one farmer in Kenya lived next to a local research site. During one cropping season he had only one on-farm trial plot on water-harvesting for which he had requested help from the local field assistant, and which was not on the agronomy experimental on-farm programme for that area. In addition he had eight of his own experiments involving superimposed, controlled comparisons, all in a field of about an acre. He had not shared the results with any of his neighbours and did not plan to do so. By contrast, another farmer from a nearby area not only undertook her own experimentation in addition to project experiments, but also organized her own field days through local women's and church groups to disseminate water-harvesting technologies. Experiments are risky ventures, and it helps if collaborating farmers are willing to take risks.

Factors hindering farmer participation

Factors that hinder effective farmer participation are mostly the reverse of the above helping factors. In particular, a strong distrust of outsiders, distrust of neighbours, jealousy, heavy involvement in local politics, limited interest in agriculture, abject poverty and an attitude of dependency will hinder effective participation.

Helping factors influencing researchers' participation

Interest

It may be assumed that researchers are naturally inquisitive and knowledge-seeking individuals who will have a strong interest in any new research topic and will soon be very knowledgeable about it. However, it is possible that they may not be very interested or knowledgeable. This happens when the research topic has been imposed from above (by a donor or senior management), and the researcher has been selected because they happen to be available. This may even apply to research based on problems identified by farmers if they are not problems that interest the researcher.

Risk-oriented

It might also be assumed that because research is about exploring the unknown, researchers will be risk-takers. But this is not always the case. They may be very experienced and faithful in following recommended experimental procedures, produce very accurate data, but be unwilling to venture into new topics or try out different ways of doing things. Such researchers are likely to spend most of their time 'exploring' the known – proving what someone else has proved already, or what they proved in their previous research or PhD. Such researchers are likely to have difficulty working under on-farm conditions, where so many variables are out of control, and where inventiveness is often required in order to work with farmers so that interesting new areas of knowledge can be explored.

Resources and mandate

Just as resources limit farmer participation, they also limit researchers' ability to reach farmers. In particular, transport is essential for researchers to get into the field, or to bring farmers to the research station. An organizational mandate for conducting research off the research station, to address problems and opportunities identified in collaboration with farmers, is a very helpful condition.

Without this clear mandate it will be difficult for researchers to venture off the research station. Related to this is the issue of incentives within research organizations for carrying out innovative research with farmers. There may be limited incentives in the form of subsistence allowances, but these do not relate specifically to the type of research undertaken or the extent to which farmers are involved in the research process.

Interest in farmers and farming

At the level of the individual researcher, an interest in listening to farmers, and learning more about what farmers do and why they do it, is a huge help to effective participation. This may be even more effective when a researcher has good communication, language and facilitation skills. Needless to say, previous positive experience of participatory research will enable researchers to go out with confidence and try out new ideas with optimism. Interest may be further stimulated when researchers participate in training courses, workshops and study tours.

Factors that hinder researchers' participation

If the researcher has a low opinion of farmers' knowledge and skills, is rigid and unwilling to take risks by trying out different diagnostic and experimental methods to suit local conditions, or by introducing a crop or variety that has not been grown before in an area, then he or she is unlikely to go far in fostering effective farmer participation. A top-down culture of research management, with limited support from research managers and peers for new approaches, is also likely to have a hindering effect. In such a case the incentives for action-learning will be very few.

A further hindering factor may be the 'donor dependency syndrome' – donors are regarded as a source of funds and a source of prescriptions about how they should be used. If the donor says there should be a participatory rural appraisal (PRA), one is done. If the donor says the research should be participatory, gender sensitive and sustainable, the words 'participatory', 'gender' and 'sustainability' appear a lot in technical reports. Genuine adoption of new approaches comes with an inner conviction that the old approaches are inadequate and new ways must be found. If necessity is the true mother of invention, then perhaps less prescriptive donor funding and more indigenous creativity is needed.

Wider conditions affecting participation

Local leadership

At the level of the community, a good measure of local autonomy and effective local authority structures will usually make it much easier for researchers to enter and engage in frank dialogue. The only drawback is that such communities are likely to have attracted other development programmes, and agricultural research is unlikely to compete effectively with other programmes for peoples' time as it may not offer many immediate benefits. Things may be more difficult if other local development agencies are unwilling to collaborate, or see research projects as a potential threat, competing for 'their' farmers. Communities with corrupt and/or ineffective local authority structures that have been long-standing recipients of relief programmes are quite likely to have a strong dependency syndrome culture that will hinder effective participation.

Development policies

At higher levels of administration, at the district and national levels, development policies and implementation provide an environment that may also help or hinder effective participation. Policies and practices that encourage self-reliance and problem-solving approaches will generally support more effective researcher–farmer participation. I saw this demonstrated, for example, in my move from Zambia to Kenya. Kenya had emphasized a strong ethos of self-reliance since independence: after initial contact with researchers, and encouragement, farmers started to form their own groups and programmes in order to improve their access to new technologies introduced through the research project. Some of the farmer research groups started their own fund-raising and input procurement activities. In one part of the project area, where a politician had been using food relief to bolster their position, it proved more difficult to motivate farmers in such activities. Food relief is another factor that tends to discourage participation in research, particularly when combined with agricultural policies that encourage cheap and unregulated food imports.

A further aspect of institutional processes relates to the way that government rural services, such as agricultural extension, are structured. If there is a top-down approach in delivering rural services, effective participation in the research process will take longer to foster, particularly if local extension staff provide the main contact point between project and farmers. Some training and re-orientation of front-line staff may be required at the start of a programme. Donor policies relating to the funding of research, and the type of conditions set, are important. While donors often push new ideas, such as 'participation' and 'gender', they tend to be impatient in expecting results, and do not allow enough time or give enough thought to fostering changes from within national research organizations.

Civil society

Related to the policy and institutional environments, aspects of civil society such as political stability and freedom of association are, on the whole, essential for effective farmer participation. Even elections may be a disruptive influence on the research process. During the multi-party elections in Zambia we found it almost impossible to conduct field PRA activities in some districts of Eastern Province, the stronghold of UNIP at the time. Extension staff had been identified as supporting the opposition party, MMD, and the district governors had banned all meetings with farmers unless a permit had been given. Related to this, support from government and donors for participatory approaches may also be a helping factor, provided that this support goes beyond rhetoric.

Technology 'supply lines'

Possibly the most helpful general condition for effective farmer participation in the research process is the existence of good 'supply lines' for new ideas and technology. One of the most frustrating things for farming systems programmes in Zambia during the 1980s was that, while very many farmers' problems were effectively diagnosed, the supply of options or solutions was very limited. The commodity and specialist research programmes were not only rather weak, but many were also initially reluctant to share technologies, such as new varieties, until these had gone through a long and bureaucratic process of variety release. It was only after good relations had developed between the farming systems teams and the commodity programmes that farmers were able to obtain access to a wider range of new technologies. By contrast in Kenya, which hosted a number of International Research Centre Regional Programmes, and had a much larger national research programme, it was much easier to access a wide range of technologies to address identified problems and opportunities. In this context, red tape, vested interests and inter-agency rivalry relating to technology and ownership of new products can be a major hindrance, limiting farmers' access to new options.

Markets

Lastly, but very importantly, the growth of markets for agricultural products is crucial in stimulating participation in research (Jones *et al.*, see p. 150). If there are poor market opportunities for crops being researched, farmers are likely to be less enthusiastic about these crops. However there may still be enthusiasm (usually from women farmers) for crops that are important to the local food system, particularly if there are problems of food insecurity at household level.

ISSUES ARISING AT THE INTERFACE

While there are conditions that favour effective participation, conditions will rarely, if ever, be perfect. Even under near-optimal conditions for effective farmer participation, a number of issues will arise when researchers start to interact with farmers. These issues relate to power, representation, trust, communication, gender and cultural etiquette, negotiation and trade-offs, varying time-scales, and a dependence on intermediaries. Awareness of the issues and how they influence the research process is the first and most important step in constructively addressing them.

Power

In the context of the agricultural research process, power has different dimensions: control of operational resources and decision-making through the cycle of research and dissemination, control of knowledge, and control of new products.

With regard to operational resources and decision-making, the power balance between researchers and farmers is rarely an equal one and is usually strongly in the researcher's favour. Researchers usually initiate the diagnostic process, decide which area to target for experiments, when to stop altogether or reduce the amount of formal experimentation, and largely dictate the terms of participation in terms of who decides on the research topic, who designs the experiment (size of plot, number of treatments, level of management), who evaluates it, and what happens to the data produced. Farmers' power in the formal experimentation process is less and is often exercised indirectly. Occasionally they may refuse to participate, either at the start of the process or in the following season after they have experienced and fully understand the terms of participation. During problem diagnosis, farmers may purposely give misleading information, either to make fun of researchers or because they do not trust or believe the stated purpose of a survey or PRA exercise. During experimentation they influence the result of an experiment by the way they allocate their land and labour to it, commonly allocating researchers their poorest land which may contain sources of variation such as a termite mound or a rill. Farmers may 'adjust' experimental management by not implementing certain tillage or fertilizer application operations as agreed or instructed. They may give feedback to researchers on the results of an experiment, but not always honestly – often there is a tendency to be over-flattering about a researcher's technology because they do not want to appear rude or critical, and also because they want to have the attention and inputs associated with a trial the next season. If farmers are not happy with the results from a trial, they may negotiate for compensation or changes in the next season.

Farmers certainly reach their own conclusions about the technology under test, which is perhaps the most important and conclusive form of power they have. This power can also lead to frustration if they cannot gain access to a technology they like after trying it out. This happened in Central Province of Zambia in the 1980s when experimental hybrid maize varieties and herbicide trials were undertaken on-farm. Farmers kept asking where they could buy a particular hybrid maize they had tested and had good performance on-farm, but which was never produced commercially due to the higher cost of seed production and the fact that it did not perform as consistently as some other hybrids in the national variety trial programme. They also could not gain access to the herbicides they had tested due to a shortage of foreign exchange for importation, and difficulties in persuading suppliers to package herbicides in a size suitable for smallholders.

Control of knowledge and new products is an extremely important source of power, and an area for potential conflicts of interest to arise, both within the research community, and between researchers on the one hand and extension and development agencies and farmers on the other.

In Zambia, when the farming systems research programmes started in the 1980s, it was common for them to present the results of on-farm variety trials at national research meetings alongside the results of national variety trials. Often these results conflicted, and the farming systems agronomists would argue strongly in cases where a variety that had performed modestly overall in national variety trials had performed particularly well in location-specific trials and was in high demand from farmers. A simple solution would have been to release the varieties performing well under on-farm conditions as well as those doing well overall in national variety trials. However, the centralized system of variety release, with very high standards of experimental data required, did not facilitate such a solution. Often this became an issue of personal pride on the part of the researcher involved. In the event, these conflicts of opinion did not substantially hinder progress in cases where local development programmes took up seed multiplication of promising varieties (both officially released and unreleased) that were popular with local farmers. Progress in the national breeding programmes was hindered, however, if breeders did not take on board lessons from the on-farm trial results and were slow to incorporate farmers' preferences into their breeding and selection criteria.

By the 1990s the situation had changed, particularly with the liberalization of the seed industry. In the case of the grain-legumes programme, the breeder adopted a very progressive approach and provided the farming systems teams with a large number of potential lines from which to select promising varieties. Farmer evaluation of these lines was the main criterion by which they were selected for local seed bulking programmes, often through farmer research groups. This proved to be a more cost-effective approach than conducting a large national programme of variety trials driven by the need to convince a national committee.

Researchers in national agricultural research systems (NARS) are in a privileged position with regard to access to new information and products. Their links to the international agricultural research (CG) centres, their access to journals and information on the internet, and the national mandates held for particular commodity or thematic research, put them in a potentially powerful position in relation to other actors. This is particularly apparent in the case of national plant breeding programmes, where access to new products in the form of germplasm is often fettered by regulations relating to variety release, and by issues of germplasm 'ownership' in cases where commercial seed interests are at stake. These regulations are well-intentioned, but often cumbersome and dated in the context of an increasingly liberalized seed supply system (Tripp, 1997). In cases where non-hybrid varieties are involved and there is limited interest from commercial seed companies, there is a strong argument for participatory varietal selection programmes. Such programmes could be implemented by a wide range of agencies (NGOs, extension, seed-growing farmers' groups, and the technical staff of research substations belonging to government and agricultural colleges). This would require a change in behaviour and attitude on the part of some national commodity research programmes – a shift away from controlling and blocking behaviour towards attitudes that facilitate other agencies (closer to the farmers and including farmers themselves) to assist with the selection and dissemination of alternative crop varieties.

An unhealthy imbalance of power during the research process has disadvantages. Farmers who are not empowered to speak out frankly will allow researchers to carry on doing something which looks stupid to them, and researchers may fail to learn much from such farmers. This imbalance of power is likely to continue as long as farmers do not have an effective influence on how research budgets are allocated. It means that genuine participation will have to be worked for by the researcher through consciously involving and empowering farmers during all important decisions. This can be done in a number of ways, including rewarding frank expression of opinions and ideas for experimentation; making extra efforts to provide information about the purpose of an experiment and the biophysical processes being explored; encouraging farmer–farmer interaction during the experimental cycle; providing farmers with experimental inputs and giving them a free hand to use these in conducting their own trials; conducting dissemination-oriented research that enables farmers to access promising new technologies (e.g. on-farm variety screening linked to local seed production schemes).

Building trust

At the start of the research process, farmers may be unsure of the researchers' motives, as was the experience of the FSIPM Project (Lawson-McDowell, see p. 21). They may have had negative experiences in the past with other projects, particularly those which may have threatened to take some of their land away. If sensitive information is being collected as part of the research process, they may wonder if the researcher will respect promises that this information will be kept confidential. The farmer may not be confident in researchers' professional judgements, particularly if an experimental plot gives poorer results than the farmer's own plot. This lack of confidence will be exacerbated if the researcher does not take time to report back the results of research and discuss these with the farmer. Signs of limited trust on the side of farmers include evasive behaviour, token participation (e.g. coming to meetings but saying little or nothing, agreeing to host an experiment but taking limited interest in it), lack of openness, and giving misleading or wrong information.

Researchers may be unsure about farmers' knowledge, for example, how far to believe what farmers say about problems and their causes during diagnosis. Researchers may also have limited confidence in farmers' ability to manage a formal experiment 'faithfully' (as agreed or instructed), or to make judgements about which treatments are most likely to be effective under on-farm conditions. Researchers may also doubt farmers' commitment to longer-term processes of experimentation and data collection. On the side of the researcher, lack of trust is signalled by strenuous efforts to control inputs into the experimental process, from design through to selection of within-farm sites, layout of plots, management, and evaluation of experimental results. Great weight is placed on replication over a range of environments and appropriate statistical analysis.

Representation issues

Representation is a central element in genuine participation and is linked to advocacy. The principle of representation is that farmers should have a voice and influence important decisions relating to research focus, methods, timescale, ownership of results and allocation of budgets. Token representation, by inviting farmer representatives to attend annual research planning meetings, may be less effective than none at all. Advocacy is needed when a group requires assistance to represent itself.

There are many obstacles to achieving meaningful farmer representation within most developing countries, particularly in the absence of strong farmer organizations with a capacity to articulate the needs of their members. There are huge numbers of farmers but only a few researchers operating with finite capacity and resources. Farming populations are diverse socio-economically and culturally, live in a wide range of environments, have high rates of illiteracy and limited access to information about technical opportunities, and lack the skills of technical language and advocacy to effectively represent their interests. Researchers are used to taking autonomous decisions, are able to represent their own interests at research agenda level, but are frequently not in touch with farmers' real situations. Moreover, researchers are often not effective in influencing national resource allocation to research, even if they have a research agenda that represents farmers' interests, and hence they may not effectively represent farmers, particularly the resource-poor.

Thus, in addition to well planned advocacy, farmers' participation in the research process becomes potentially the most practical form of farmer representation. This has implications for the selection of representative research sites in which research can be conducted that addresses priority problems and prime market opportunities. In the longer term there is a need to develop more effective farmer representation mechanisms, probably through producers' associations. However, even with strong farmers' associations the interests of women and poorer farmers are likely to be poorly represented, and explicit advocacy strategies for representing the interests of these groups will be necessary.

Communication issues

Communication skills are an important tool for farmer-oriented research. Agricultural research in general, and ICM in particular, is very much a knowledge-based process. It follows that poor communication of knowledge is a serious impediment to effective participation and collaboration between researchers and farmers. Farmers are most often skilled communicators within their own environment using their local language, but have limited grasp of the European scientific terminology and concepts used by researchers to explain what they do and understand, even when talking in the local language. Once faced by agricultural scientists who are comfortable in the role of an expert giving advice, farmers may withhold much of what they know. During meetings between farmers and researchers, women and youths are often constrained from giving opinions and are effectively excluded from the communication process. Often the pattern of communication is that of male researchers talking to male farmers, and the researchers may have limited skills in the local language – especially to present scientific concepts. Often it will be necessary to have meetings with specific gender and/or age groups in order to obtain the views of all the main farmer stakeholders.

In order to minimize misunderstandings, techniques are required for communicating more complex ideas. For example, appropriate use of visualization methods such as diagrams, pictures, flow-charts or participatory ranking may significantly improve communication between researchers and farmers in certain circumstances.

Cultural etiquette and gender

Related to issues of communication, the local cultural etiquette for dealing with important visitors and outsiders may impede effective communication. Often local culture requires that visitors be treated with deference; it may be considered rude to contradict an opinion or idea expressed (or implied) by an outside visitor. As a result, farmers often have difficulty in giving frank opinions, particularly if these opinions are negative. Women in particular may be shy, for cultural reasons, to volunteer information and initiate dialogue with outsiders. Researchers too may find it difficult to say no when responding to requests for assistance. They may also find it hard to be the bearer of bad news, particularly when starting and finishing a project. It may be hard to tell a farmer that you have no easy solution to a problem they have identified, or that the project is going to finish and there will be no more visits and inputs associated with trials. Undue attention to politeness for fear of giving offence results in important facts and opinions surfacing late in the research process and promises made to keep the peace being broken, negatively influencing relations with farmers. While attention to politeness and respect is paramount in building relations, there is a need, early on, to find ways of introducing transparency and greater accountability. This may be very hard where there is limited trust on both sides. Some type of contract, verbal or written, may be a way of moving forward to address this issue. Another way is to raise the issue of the need for openness during early discussions in the research process, and for the researcher to demonstrate this openness in small ways (for example, by acknowledging lack of knowledge when asked a difficult question, or by politely saying no to a request, giving reasons why the answer is no).

Negotiation and trade-offs

Researchers and farmers start with different agendas (Long and Long, 1992). Therefore negotiation and trade-offs on both sides will be required for effective participation in the research process. Farmers usually start from a position of weakness in negotiation with researchers. They may not be used at all to negotiating with outsiders. Even if they are, they are probably new to agricultural research and therefore unsure about what is on offer, or the implications of refusing to collaborate. They may be too optimistic, expecting free inputs for an extension demonstration plot, or pessimistic that they will be given inputs on credit that they will have to pay back, or that researchers will come and harvest the plots and take away the produce. Farmers also may not be clear about who in a research team has power to change anything, and, therefore, with whom they should try and negotiate. Once farmers have a better understanding of what research has to offer, they still have to consider the trade-off between the extra time and other resources involved in running an on-farm trial and other activities. If they agree to a trial, poorer farmers may face a further trade-off between immediate needs and gaining new knowledge. For example, if given seed for a variety trial they may eat the produce of all of the plot, rather than saving some of the seed in order to evaluate varietal performance over a number of seasons. To reduce the negative influence of such trade-off issues on the research process, it may help if negotiated agreements are reached between farmers and researchers once dialogue has been established.

Not every researcher may see the need for, or the benefit from, negotiation with farmers. In the worst-case scenario, the researcher may have a pre-determined plan to implement on individual farms, and adopt a take-it or leave-it attitude. Alternatively, the researcher may wish to negotiate a favourable site within the farm, and in return be prepared to compromise on implementation and layout.

For example, in Lusaka Province of Zambia during the early years the farming systems team testing new maize varieties were always given the least uniform and most infertile sites by farmers. Through negotiation with farmers they obtained large and uniform sites by superimposing the variety trial onto the farmers' system of planting maize behind the plough, and achieved much better experimental results which they could use to inform extensionists and seed suppliers. The researcher may also be constrained by not knowing who, within a household, to negotiate with, as in the example of the Kenyan soil fertility trials described above. The most common trade-off that researchers face is between close supervision of a small experimental programme, and delegation in order to expand its topical scope and area coverage. Delegation of decision-making to farmers, more 'farmer-managed' and collaboratively designed trials, involve this type of trade-off.

Signs that negotiations have been balanced and the trade-offs recognized include: clear agreements about who will do what; greater farmer understanding of the purpose of experiments; and greater satisfaction with data (quantitative and qualitative) generated by both researchers and farmers. Signs of ineffective negotiation in which trade-offs have not been thought through include limited ownership by farmers of the research process and experimental results; poor trial management by the farmer; and frustration on the part of the researcher.

Time-scale issues

As agendas will differ, so will time-scales. Farmers' views of time-scale issues are likely to change as the research becomes more participatory. At the start, when they are largely accommodating the researchers' needs, they usually expect fast results from trials. If material benefits are significant they will also want the trials to continue for an indefinite period.

When farmers are given a significant say in setting the research agenda they may start to expect a constant flow of new ideas and products from the researcher (Sikana, 1994; Sutherland, 1997).

Researchers are usually bound by project objectives, the project cycle and experimental standards of their discipline, and also sometimes by technology release committees that require 'conclusive' results. This tends to mean an abrupt start and end to their experimental activities. If the researcher is involved in measuring long-term biophysical or socio-economic changes or trends this may require a drawn-out process of data collection and dialogue with farmers, but with no immediate or obvious benefits for the farmer. Exit strategies therefore need some careful thinking about long before an on-farm research programme ends, so that differing expectations relating to time-scales are addressed.

Intermediaries

A final but very important issue relates to the use of intermediaries in the research process. The quality of the research process, including farmer–researcher dialogue, very often depends as much on the skills and attitude of the intermediary as it does on either the researcher or the farmer.

A common scenario is for researchers to talk to farmers during problem identification and perhaps also prior to planting of experiments, and then to rely a great deal on intermediaries for experimental monitoring and implementation. Researchers have to trust intermediaries, who they do not always choose, but who may be assigned to work with them by research or extension managers.

Even if the researcher intends to hand over decisions to the farmer during implementation, a well-intentioned intermediary may frustrate this plan. 'Farmer-managed' trials may end up as trials that are managed by the front-line extension or technical staff assigned to monitor the trial. If these staff have not been trained in participatory approaches they are likely to give out a set of rigid instructions, rather than guidelines and options. Thus researchers need to consider carefully at the start how much can be delegated to intermediaries, and think of ways of empowering them via appropriate training. This may include training in empowerment approaches, and farmers may also be trained as in the Kavango farming systems project in Namibia (Matsaert and Bagnell-Oakley, 1997).

Farmers should also have confidence in the intermediaries used. Farmers depend for most of their information and guidance during the research on the front-line technician assigned to monitor the trials. If that person is a local extension worker, farmers may have had negative experiences with him or her that will influence their potential participation.

Intermediaries can potentially pose a barrier to effective researcher–farmer interactions. This is likely to happen if researchers see them as a means for implementing large on-farm experimental programmes in order to generate a lot of useful data that will be analysed by the researcher in his or her office, and show relatively little interest in two-way dialogue with farmers.

FUTURE CHALLENGES FOR PARTICIPATORY ICM

Some of the challenges facing effective farmer participation in more formal ICM-related research have been alluded to in the introduction. Three types of challenge stand out as deserving attention from researchers who want to move ahead with this line of research.

Methodology: striking a balance

There is need to strike a healthy balance between formal experimentation, modelling and informal qualitative research.

Formal technical research using conventional experimental methods, backed up by sophisticated laboratory and statistical methods, is an expensive process. Conducting this type of research under farmers' conditions can be frustrating (both for farmers and researchers), as the FSIPM Project has testified, and may take up a large amount of project resources. Frustrations can arise if complex experimental designs are used that make it difficult for farmers to understand the rationale behind an experiment. There is a need to balance ideal biometric considerations with what is both practical and accessible to farmers' understanding (Martin and Sherington, 1997). It can also be particularly frustrating if, during the experimental period, weather patterns create pest and disease behaviour and crop responses to soil fertility inputs that are untypical. Given that the chances of a 3-year project being able to find typical climatic conditions for on-farm experimentation are rather low, the implication is that other methods are also needed to complement formal experimentation.

One alternative, where formal experimentation is a high-risk approach in terms of obtaining typical results over a short period, is to use models. Quantitative modelling of biophysical responses and economic returns is a developing art. Much will depend on finding the appropriate model for a particular task, and being able to feed accurate information into the model without having to undertake a major set of additional research activities. The worst-case scenario is when the need for complex predictive models, rather than the need for technical solutions to problems and opportunities, drives the experimental process. There is more promise where the approach to modelling is simple, and farmers are involved in the modelling. CIMMYT's work on soil fertility (Vaughn, 1999) and the work conducted by the FSIPM socio-economics programme (Mwale *et al.*, see p. 102) are examples of how more simple types of modelling can be applied to ICM-related on-farm research.

Informal and qualitative approaches offer a valuable research tool that is not always used to optimal potential. Very often this is a result of limited experience among the research team of qualitative/PRA methods. As a result, PRA tools are often used simplistically and mechanistically during problem identification and priority-setting exercises. The challenge is to use these tools more effectively so that farmers' knowledge is more fully utilized in research priority-setting and experimental design. The way forward in this respect is shown by work currently being undertaken under the African Highland Initiative (AHI) programme (Stroud, 1999).

Building sustainable relations

A second area of challenge is how to build more sustainable working relations between researchers and farmers in ICM research. Research projects, FSIPM included, often invest considerable time and resources in building up good relations with farmers in local communities and building up their capacity to undertake more formal experimental activities. At the end of 3 years farmers are likely to be hungry for more involvement in research, just when researchers are preparing to close down experiments. If the focus of research is ICM-type issues, then 3 years is a very short time in which to conduct experiments and observe any impact, except perhaps that achieved by the introduction of more disease- and pest-resistant varieties. This implies that research projects should be funded over longer periods of time, with a component for local capacity building (at community level and above), and strong linkages with relevant development programmes. Agriculturally oriented NGOs with an interest in sustainable agriculture and marketing issues would be obvious partners for building a more sustainable relation between researchers and farmers in ICM research. Other potential partners would be companies or growers' associations with an interest in more integrated and sustainable production methods.

In addition to building sustainable working relations with farmers and other agencies, more attention is required to building greater continuity in relations between researchers – both within national systems, across national systems and with international research systems. A more cross-cutting framework may be required to achieve this type of continuity: one example is the participatory agro-ecosystem management approach currently being used by the AHI, which uses benchmark sites and cuts across both the NARS and CG systems (Stroud, 1999). This requires a learning-by-doing approach, with adequate time and resources for reflection and further training in order to facilitate rigorous and progressive participatory and interdisciplinary research.

Uptake and sources of new knowledge

A third challenge relates to promoting uptake of research by developing operational linkages between ICM research programmes and service providers and markets. A market-driven approach to research should foster strong links between research programmes and trading and processing agencies (Jones *et al.*, see p. 150), but will not necessarily promote an integrated approach to research issues at the farm level. Large companies with outgrower schemes may promote monocultural practices with limited attention to longer-term sustainability or integrated pest and soil fertility management. Only if quality standards relate to organic produce certification schemes, or to regulations on safe pesticides use, is an ICM type of approach likely to be used in more market-driven approaches. In addition, market approaches linked to food-legume programmes may promote ICM, particularly in the cereal-based smallholder production systems of eastern and southern Africa. Linkages to agencies using more participatory extension approaches, such as farmers' field schools, are likely to be particularly important where markets for the crops involved are not highly organized and inputs are locally sourced. Links with programmes that are empowering farmers' groups to access and lobby for services may be particularly useful when it comes to uptake of promising technologies.

Links to new knowledge and product streams to feed into the research process will also be a challenge. To a great extent, adoption of an interdisciplinary team approach should foster a diversity of new knowledge sources, including the internet and worldwide web, to prime the research process. This will be further supported by mechanisms to make it easier for any researcher or development agency anywhere to access new knowledge and new products. The CG system has a major role to play in this endeavour, particularly through more cross-cutting programmes that are oriented to systems as well as commodity issues.

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DISCUSSION

J. Lawson-McDowall. In your experience is there any value in sequencing research: for example, should one or two disciplines begin before the others?

A. J. S. In my experience it is better for a core team of various disciplines to start together with problem diagnosis and opportunity exploration. Other key expertise can be brought on board to tackle particular problems as these arise through interaction with farmers.

C. E. D. Mainjeni. You indicated that technologies are available to farmers but are not fully utilized by them. What in your experience is the cause for this, and are there any practical solutions?

A. J. S. The technologies that farmers have are used by them, but not by all of them, for various reasons. Reasons include lack of resources, lack of access to these inputs, or certain local knowledge is not widely shared (knowledge is power). Researchers and extensionists may facilitate farmers to share their knowledge and practices/technologies more widely by exchange visits, open days at innovative farmers' farms, farmer experimentation, and farmer trainers to train other farmers.

Learning with farmers: participation and evaluation in the development of IPM technologies

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ABSTRACT

This paper describes the participatory monitoring and evaluation activities of the FSIPM Project and analyses the implications of the results for the work of the project. Monitoring has been an important source of feedback from farmers and has provided an opportunity for farmers, as individuals and in groups, to influence the design of the trials. Farmers have been encouraged to determine the criteria by which varieties or technologies are judged in order to to assist researchers in directing their efforts to meeting expressed needs. Among the most important findings identified through monitoring were that farmers placed high value on early-maturing varieties to help them through times of food shortage. Also, that without fertilizer plot yields would be so low that farmers would lose interest in the trials. It also became clear that extension recommendations on plot architecture were not in common use amongst farmers. Unfortunately a scoring system designed to promote internal consistency between the farmers and the trials, and to make possible the quantitative treatment of qualitative data, was found to be problematic. Farmers tended to give high scores to plots with low yield measurements. This finding has implications for much participatory technology development work, and while several explanations are offered for the discrepancy, none seems satisfactory.

INTRODUCTION

The participatory monitoring and evaluation activities of the Farming Systems Integrated Pest Management (FSIPM) Project are described, and the implications of their results for the work of the project are analysed. The goal of the FSIPM Project was to provide small-scale, resource-poor farmers with acceptable IPM strategies to reduce pre-harvest crop losses due to pests. From 1996 to 1999, the project ran on-farm trials with selected farmers in four villages in Mombezi and Matapwata Extension Planning Areas (EPAs). In these trials a range of pest management (and later crop management) strategies were tested against *Striga asiatica*, whitegrubs and termites in maize; bean fly in *Phaseolus* beans; and *Fusarium* wilt in pigeonpeas. These strategies encompassed host-plant resistance, cultural practices and some chemical pesticides.

Over the 3 years a key element in rethinking the structure and content of the trials has been the feedback received from participating farmers. The main source of this feedback has been our monitoring and evaluation exercises. We have also found it necessary regularly to review our monitoring style, to ensure that farmers could express their opinions whilst still collecting the information we needed to set alongside technical and economic results.

Why monitor with farmers?

Monitoring is the regular collection of data on an activity or technology. These data can then be analysed to determine whether technologies are meeting set objectives and, if not, what changes may be needed. Yet, not all data that can be collected are important. How do researchers or development workers decide what data to collect? They must firstly agree which criteria should be measured, and secondly establish what indicators will best inform these criteria. For example, in a project that seeks to learn which pigeonpea variety is most wilt-resistant, an obvious criterion would be the yield for each variety. An indicator of yield might be kg/ha, or a count of the plant stand.

However, the final arbiter of the success or otherwise of a technology is the client who will use the product. In a project such as the FSIPM, the end-users are resource-poor farmers, thus any monitoring activity must include criteria determined by farmers. Farmers must, therefore, be closely involved from the start in monitoring and evaluation.

Why can scientists not establish these criteria themselves? Scientists can learn about farmers' criteria only through working closely with farmers in adaptive experiments. Farmers are the experts in terms of the effect of a technology, not only on the development of their whole farm, but also in terms of their overall set of livelihood strategies of which farming is likely to be only one part. This means that farmers alone can decide if they are able to, and want to, apply the innovations suggested. Table 1 lists some factors a farmer might consider in his or her evaluation of a technology.

Criteria will also vary between households, depending on what productive resources are controlled by the household. Preferences may also vary between individuals within households: different members of a household may have divergent roles and responsibilities that mean they prioritize activities independently and differently. For example, while all members of the household may agree that they wish to

Table 1. Factors farmers may consider when evaluating a technology

Able	Want
What claims will an activity or technology make on my scarce resources (land, labour, cash, etc.) and at what times of the year? What inputs will be required? Are these available and affordable? What are the preconditions to changes in farm management? e.g. are stable output prices necessary?	Will it work under my farming conditions? Can I adapt it to suit these? Does this technology meet my priorities? e.g. does it make my farm more diversified and so less susceptible to risk? Will it overcome my problems? What are the benefits and disadvantages? Do these benefits accrue to me? Are they temporary or permanent? How will my family or the wider community react to these changes? What wider effects might the technology have? Do I like the technology?

Adapted from Van Veldhuizen *et al.* (1997).

maximize maize yield, they may differ about whether this should be done via added inputs or increased labour.

A further advantage gained by consulting farmers throughout the process of adaptive technology development is that farmers are able to bring their extensive practical knowledge of farming and their understanding of the local situation to bear on the problem. Formal research and development institutions have limited capacity to develop a multitude of locally specific technological adaptations, and are able to increase the effectiveness and efficiency of their work by collaborating with farmers. In this way, researchers are able to triangulate their results: technical data can be matched with economic evaluations and farmers' preferences.

Monitoring with farmers also enables researchers to compare their objectives to those of the end-users and to identify any contradictions between the two. Where necessary, this permits a re-orientation of practice and goals on the part of the researcher.

FIRST ATTEMPTS AT MONITORING

The first year's trials were set up as an incomplete factorial design with a fractional replicate, one plot on each of the 64 farms being used as the experimental unit. This permitted all relevant two-factor interactions to be estimated from the data (Abeyasekera, 1998). This complex design was necessary because several of the technologies inherited by the FSIPM Project required testing rather than adapting (as had been envisaged). Included in this set were farmer technologies suggested by trial participants.

The drawbacks of this design from the farmer's point of view became quickly apparent and were made concrete in the evaluation exercise. Farmers were able to see only one treatment combination and were therefore unable to observe the effect of the different treatments. Furthermore, in some cases more than one treatment per pest was specified, so that it was not possible to distinguish discrete causes with the naked eye. These problems were compounded by the absence of fertilizer and the exceptionally heavy rains of the 1996/97 season which led to poor harvests. There were also 'problems' with an absence of pests, either due to misidentification of infested areas, as with *Striga*, or the heavy rains which kept down the bean stem maggot and termite populations, or flooded the *dambo* area where whitegrub infestation was highest.

However, despite these uncertainties, farmers were able to put several messages across very clearly. Firstly, all were unhappy that no fertilizer had been applied. Farmers stressed that the fertility of their soil was so low that, without fertilizer, there would be no crop on which pest damage could be assessed. Clearly, farmers would not be enthusiastic about trials where they could see no visible benefit. Inputs alone were insufficient. (This message persisted despite growing farmer confidence about compensation in the event of crop failure.) Secondly, farmers could not evaluate treatments where they either did not understand the nature of the pest or disease (e.g. *Striga*) or where they could not see a direct connection between the treatment and the pest or disease (e.g. high-density planting against bean stem maggot). Thirdly, farmers' criteria for assessing the pest management strategy referred to aspects of their farming systems other than maximization of yield through pest or disease control. Farmers objected to strategies that increased labour (e.g. earthing up) or required inputs that were not readily available (e.g. mulching with grass).

Methods

The evaluation exercise in 1997 concentrated on the 32 farmers best able to assess the results (i.e. with fewest treatments) in the individual open-ended question sessions, but included all farmers in the group evaluations. This combination of individual interviews with open-ended questions and group evaluations has been continued throughout the life of the project.

Individual interviews incorporating open-ended questions have been at the heart of the monitoring exercise. Group interviews are important as, in addition to being quick and efficient, they stimulate discussion where farmers disagree or have had very different experiences. However, there is always the danger that particular individuals will dominate or be reluctant to speak, or that members may hold back on opinions that buck the trend, leading to a false consensus.

Individual interviews, although time-consuming, allow everyone a voice and permit representatives of a range of socio-economic situations to give their views privately. This approach also allows the further development of effective communications between researchers and farmers. Finally, it has enabled us to compare farmers' ratings of individual plots against technical measurements from that plot.

Open-ended questions are an important element at certain stages in any participatory work, as they make it possible for opinions of the client to be expressed spontaneously rather than for the researcher to impose his or her categories. During the life of the FSIPM Project, open-ended questioning in monitoring has been used extensively year on year. The information gained is qualitative but can be treated quantitatively, e.g. individual answers can be coded and counted over the larger group.

SECOND AND THIRD YEAR MONITORING

Simplification

The evaluation findings were taken on board when designing the 1997/98 trials. The number of treatments per crop was reduced to three for maize and one each for beans and pigeonpea. Treatments rejected by farmers were excluded. The research plots were divided into four sub-plots so that most of the treatments were visible to each farmer. This design still left combinations of varieties of beans and pigeonpea with maize seed dressing or banking unreplicated on each farm, since it appeared reasonable to believe that interactions would not be discernible by the farmers, whereas the relative performance of varieties and the presence or absence of banking or seed dressing would be things which farmers could easily understand or evaluate. Any interactions between bean and pigeonpea varieties, or between each of these and seed dressing or banking, will be detectable in the statistical analyses of yield and plant survival (Ritchie, 1998). Fertilizer was included in the input package. On the monitoring side, it was decided that farmers' criteria should be sought in a more systematic fashion. The exercise should be expanded and made more amenable to quantitative analysis, and means of quantifying qualitative data should be sought.

This resulted in a two-stage exercise. Firstly, open-ended interviews were conducted with six farmers, three from each EPA, to establish key criteria used by farmers to evaluate varieties or cultural practices. On the basis of these, a questionnaire was designed that blended open-ended questions, researchers' criteria and farmers' criteria elicited from the early round, yet allowed space for spontaneous comment. Following advice from project statisticians, farmers were asked to score for the qualities mentioned or listed to give internal consistency between questionnaires and permit statistical analysis of these qualitative data.

In this monitoring exercise, a wide range of topics was covered in addition to evaluation of pest management strategy. Farmers were asked if the criteria we had listed were important to them, and what problems in general they had faced with their crops. We inquired about farmers' own varieties of maize, beans and pigeonpeas, about their cultural practices (such as ridge and plant spacing or intercropping), and their opinions of our design. Each problem or variety was scored from 1 (not a problem/bad) to 5 (a very serious problem/very good) and summary questions were asked to cross-check. Scoring took place at the research plot itself. We also questioned farmers about reasons for problems with certain project activities resisted by farmers (e.g. *mbwera*: planting a relay crop in the furrow filled with earth from flattened ridges after the bean harvest). The history of pest problems in a particular plot was also recorded. Finally, farmers were invited to contribute directly to project design by suggesting the changes they would like to see in the following season's trials. Monitoring took place in stages appropriate to the development of the crop: the first in April–early May, focusing on beans, banking, *mbwera* and seed dressing. The second, in June, was concerned with maize and fertilizer use and the progress of the pigeonpea and the relay bean crop.

The final evaluation of the pigeonpea harvest took place in September 1998, but followed a different format. Team members took advantage of a training course in participatory technology development to experiment with different group methods of evaluation. The techniques attempted were felt to be interesting and extremely quick in terms of farmers' time and writing up, but not to offer the scope for comparative analysis offered by the individual questionnaires.

From 1997 onwards, group monitoring was undertaken through Farmer Field Days. These events had two functions: feedback prompted by discussions, observation and comparison, and the dissemination of information. Farmers invited relatives, friends or neighbours, and the project invited local extension staff to these events. A visit was normally made to a selected trial plot in the respective villages, where the owner of the field would explain the experiment and questions and answers were encouraged. Farmers were again asked to think constructively about what they had disliked about the trial by suggesting alterations for the following year. This was also intended to encourage a greater sense of ownership on the part of the farmers.

Rather than discussing the results of the second year's monitoring exercise at this point, a brief account of the third year's monitoring exercise follows. This is because similar themes arise from the experiences of the two seasons. The third year trials built quite closely on the work of the second year. The extensive questioning of the previous season could be pared down as we had acquired so much data about farmers' preferences. Nonetheless, open-ended questions and questions about farmers' criteria remained central. The two big differences between the second and third years were: (i) there was an additional plot to monitor, the farmers' observation plot (or, as it became known, the *kanthu nkhako*, 'our own thing' plot); (ii) since not all farmers have particular pest problems (e.g. whitegrubs and termites), but those who do have a serious problems, trials aimed at reducing whitegrub and termite damage were focused on those farms where most damage had been measured in the previous year. The

Table 2. Most serious general problem with beans

	Percentage of farmers mentioning a problem		
Beans	Rain	Wilt	'Burning' of leaves
1997/98	48	15	10
1998/99	89	22.8	43

remainder of the trial, the 'main' trial, continued to look at varietal resistance to wilt in pigeonpeas and bean stem maggot resistance and early maturity in beans. This targeted approach had been adopted with the *Striga* trials from the start.

The *kanthu nkhako* plot was a compromise between the desire of the FSIPM Project to have farmer-designed and managed plots in the final year, yet to continue with trials that were scientifically verifiable and the results of which could be communicated to the wider agricultural research community. All farmers taking part in the trial were given a replicate set of inputs to plant. The project asked only that *kanthu nkako* plots should be close to the research plots to allow comparison, but otherwise left farmers alone to do whatever they wished with the inputs.

PROJECT LEARNING THROUGH MONITORING EXERCISES

Farmers' preferences

The open-ended questioning in the second-year monitoring established that for beans, yield (cited by 75% of respondents), early maturity (53%) and taste (50%) were the most important criteria, followed by marketability (30%) and cooking time (23%). For maize, yield (83%), early maturity (62%) and seeds per cob (29%) were what mattered. Pigeonpea problems were ranked by four groups of trial farmers as yield (1st), taste (2nd), cooking time (3rd) and vigour/firewood/height (4th). However, only four farmers (out of 40) mentioned pest resistance as a criterion for evaluating bean or maize varieties. This confirmed the growing understanding amongst project members that pest management was not the farmers' priority.

These results were reinforced by farmers' scoring of varieties. In the 1997/98 season, Kaulesi was the most popular bean variety, chosen because it is high-yielding and early maturing. In maize, the early maturing hybrid NSCM 41 received the highest scores. (It should be noted that there was no statistical significance to the difference in scores given to Masika and MH18.) For pigeonpea, ICEAP 00040, high-yielding and (for a long duration variety) early maturing, was ranked first. In 1998/99 maize varieties were not compared, but the most popular beans (Kaulesi, Mkhalira and Kambidzi) and pigeonpea varieties (ICEAP 00040 and Chilinga) were, again, high-yielding and early maturing varieties.

Researchers on the project had expected yield to be an important factor, but had not realized how much emphasis farmers placed on early maturing varieties. Farmers explained this was because they provided food during the pre-harvest period when many were very short of food and had cut back to two meals, or even one meal, a day.

Which problems were considered serious by farmers?

In each farming season, farmers were asked to say which pests, diseases or general problems they had encountered in their farming. The most serious general problem was with beans (see Table 2). Although technical measurements of the seasonal variation in important pests and diseases were also taken every year, it was important to record farmers' perceptions of these problems. Were major discrepancies found, this would indicate a gap between farmers' and scientists' priorities and understanding.

Pest populations and disease prevalence have varied year by year. This means that in a 3-year project, pests or diseases that, over a longer timespan, cause serious damage may not be represented. This can be seen in Tables 3 and 4 where, apart from *Ootheca*, farmers mention different pests on beans for each year.

Farmers were also asked to score their plots for whitegrub and termite populations. As Table 5 demonstrates, damage from whitegrubs and termites was erratic and variable, even in the 1998/99 trials when trial participants had been selected on the basis of evidence of damage.

Pigeonpea

It appears from FSIPM Project work that pigeonpea does not grow well in the slightly damper and cooler weather of Matapwata EPA. Farmers' views on the severity of pigeonpea wilt are not available for 1997/98, but the results for 1998/99 suggest that wilting was not an important problem. When

Table 3. Most serious pest problem in beans 1997/98

	Percentage of farmers mentioning a problem			
Beans	*Ootheca*	Sucking bugs	Whitegrubs	Aphids
1997/98	40	5	5	5

Table 4. Most serious pest problem in beans 1998/99

	Percentage of farmers mentioning a problem			
Beans	*Ootheca*	Snails	Elegant grasshopper	Pod borer caterpillars
1998/99	40	17	11	11

Table 5. Whitegrub and termite populations 1997/99

Year	Whitegrub	Termite
1997/98	About 50% of farmers in on-farm trials observed whitegrub damage on the research plots. Six said it was more serious than the year before	About 18% of farmers in on-farm trials observed termite damage on the research plots. Six said it was more serious than the year before
1998/99	Three of nine whitegrub trial farmers noticed slight whitegrub damage on untreated plots	On average, eight of 12 farmers reported no termite damage in the research plots*

*Average taken across the four different types of plot in each farmer's field.

asked the most serious general problem for pigeonpea on the farmers' observation plots, only two of 18 Mombezi farmers evaluating the medium and long duration varieties mentioned wilt. Similarly, when asked directly if wilt had been a problem on the medium duration varieties, half the Mombezi group said that it had not, and when asked about the long duration variety in the next monitoring round, 12 of 17 said that it was not a problem. In Matapwata, out of 13 farmers only one said wilt was the most serious problem. Only three farmers said wilt was a problem when asked directly.

Farmers' practices

Through looking at farmers' fields around the research plots in the second year and at the *kanthu nkako* plots in the third year, much was learnt about farmers' agricultural practices from the monitoring exercise. It became clear that the architecture of the research plot differed from the 'average' farmer's field in several important ways. For example, farmers' ridges were often smaller and closer together than the project's large, 90 cm distant ridges. Most farmers planted their maize 50–80 cm apart rather than 90 cm as on the research plots. Farmers felt that such wide spacing wasted land and that a larger harvest could be gained if more maize seeds were planted per row. We also learnt that there is enormous microvariation in the intercropping pattern, both with different crops and combinations thereof. Just under half of the farmers did not approve of intercropping both beans and pigeonpea with maize at the same time, a planting pattern that had been thought standard for the area.

Opinions about techniques, inputs, process and timing

Farmers used the evaluation sessions to make their opinions clear about processes that they did not like. The clearest example of this comes from the input closest to farmers' hearts – fertilizer. In 1996, when no fertilizer was applied, farmers complained bitterly and voted with their feet in abandoning plots with miserable harvests. In 1997, when fertilizer was applied, but in one dollop soon after planting (less than the extension recommendation), 73% of those interviewed said that they thought our practice would lead to a reduced yield. By the 1998 season, farmers appeared to have accepted project practice, since few comments were made.

Feedback about co-operation with the project

Regular monitoring was also very important for improving the degree and extent to which farmers were participating in the project. This topic is addressed more fully in a companion paper (Lawson-McDowall, see p. 21), but is summarized here. Whereas the first year's trials had been too complicated for farmers to evaluate treatments, the second year's trials fell down in a different way. The trials were simple enough, but monitoring showed that there had been a failure to maintain farmer participation. Too often, farmers had not been included in important activities which would have enabled them to recognize varieties or judge interventions, such as planting or fertilizing. The heavy workload of the technical team and an on-station trials mentality that was being only slowly eroded meant 'getting the work done' took precedence over communication with farmers.

This problem can be quantified. Only 19 of 40 farmers in the main trial had taken part in planting in 1997. Out of 40 farmers, four had helped apply fertilizer, five took part in the bean harvest and six in the maize harvest. Clearly, as far as participation goes, the project was moving backwards, towards a relationship with farmers based on the use of their land and labour in exchange for inputs, but asking them to contribute little else, in the 'contract' style described by Biggs (1989).

In the third year, therefore, a training course in participatory approaches was arranged for all staff members, and implementation meetings were set up with farmers. At these meetings farmers and project staff negotiated about which events farmers wanted to take part in and which the project wanted the farmers to be involved in. A timetable of events was agreed, as well as who the technical team could meet if the farmer him or herself were not available. Farmers' participation was then 'institutionalized' through check boxes on technical team monitoring forms.

Suggestions for the following year

Participation in the 1997/98 season was maintained insofar as monitoring encouraged farmers' suggestions for the next season's trials (and, in fact, for which bean would suit the *mbwera* bean crop in the 1998 season). Several farmers asked for narrower maize spacing, 18 said later fertilizer application would be a good idea, and preferences were expressed on varieties.

Table 6. Farmers' learning from the *kanthu nkako* plots, main trial, post-germination monitoring

What farmers hoped to learn about	Frequency	Percentage
Compare vigour, maturity and yield of these different varieties of bean and pigeonpea to local varieties	13	32.5
Grow new and different varieties of pigeonpea and bean and assess their yield	8	20
Planting definite numbers of seeds and their spacing	4	10
Assess the yield and taste of these varieties	2	5
See difference in yield and ability to tolerate pests	1	2.5
Obtain new seed for future use	1	2.5
Unable to tell	4	10
Learn nothing	7	17.5
Total	40	100

THEMES REVEALED BY MONITORING

Throughout individual and group monitoring, various themes could be discerned.

Farmers' priorities

Firstly, farmers' priorities were not easy to discover except through persistent questioning. By way of illustration, while yield was clearly the most important criterion it took some time to see how other factors, such as pest resistance, were inseparable from the notion of yield, and how yet others were important in their own right, as with early maturity. It is generally understood now that pest management is not a priority for most farmers in the project area. Low soil fertility is the main problem. This has been seen particularly in farmers' keen interest in green manure technologies. It also took project personnel time to appreciate how, in the context of a range of livelihood strategies in addition to farming, trial participants would abandon plots where a very low yield seemed certain in order to pursue more profitable options. This means that farmers cannot be engaged purely as experimenters, but must see promising results on at least part of their plots if they are to remain enthusiastic.

Farmers' confidence

It also appeared to project staff that farmers became better at monitoring as time went on. They were more confident about offering criticism, expected project staff to come and ask about varieties and practices, and were altogether readier to answer a range of questions. Most farmers appeared happy to have a range of new varieties to try out and were particularly pleased with the idea of the *kanthu nkako* plot. The scoring results showed internal consistency. Participants mostly matched cross-checking questions such as 'What is the most serious overall general problem' with the answers they had given earlier.

The style of monitoring adopted here allowed farmers to influence the form and content of a rigorous scientific research project. Every farmer had the chance to comment on all aspects of the trial. The approach also allowed us to combine quantitative and qualitative approaches, and to generate qualitative data that could be treated quantitatively (as discussed below). This allowed for comparison across varieties, techniques, farmers, villages and EPAs, and by gender.

However, from the perspective of the monitors certain frustrations arose. The first was that trial members often commented on what we considered irrelevancies. The second has arisen from comparing farmers' scoring of varieties with measurements of yields.

Plot design

The so-called 'irrelevancies' were the fact that farmers continually mentioned the 'architecture' of the plot: the spacing of ridges, their height, distance between planting stations, intercropping, etc. This made us realize that we should have studied farmers' practices more closely at the beginning, rather than adopting extension recommendations. Having such a different layout was a distraction from the main focus of the trial.

The kanthu nkako *plots*

The solution to this problem was discovered almost by accident. It had been the intention of the project to move towards farmer-designed and managed research plots in the final year. However, when it was realized that this would fail to generate the technical data required, it was decided to run two plots. The first, as before, would be researcher-designed and supervised but managed by the farmer, where pest and yield data could be collected. The second would be under the farmer's own design and management. The inputs alone would come from the project and would (approximately) duplicate those used for the research plot.

Team members delved into local sayings and proverbs to come up with the name *kanthu nkako* ('our own thing') for the observation plots. The concept and practice were immediately popular. To our surprise, farmers talked much more about varietal differences and much less about the layout of the plot than when discussing the research plots. Compare, for example, Tables 6 and 7 from the post-germination monitoring of the main trial. Table 6 lists farmers' comments about what they hope to learn from the *kanthu nkako*, and Table 7

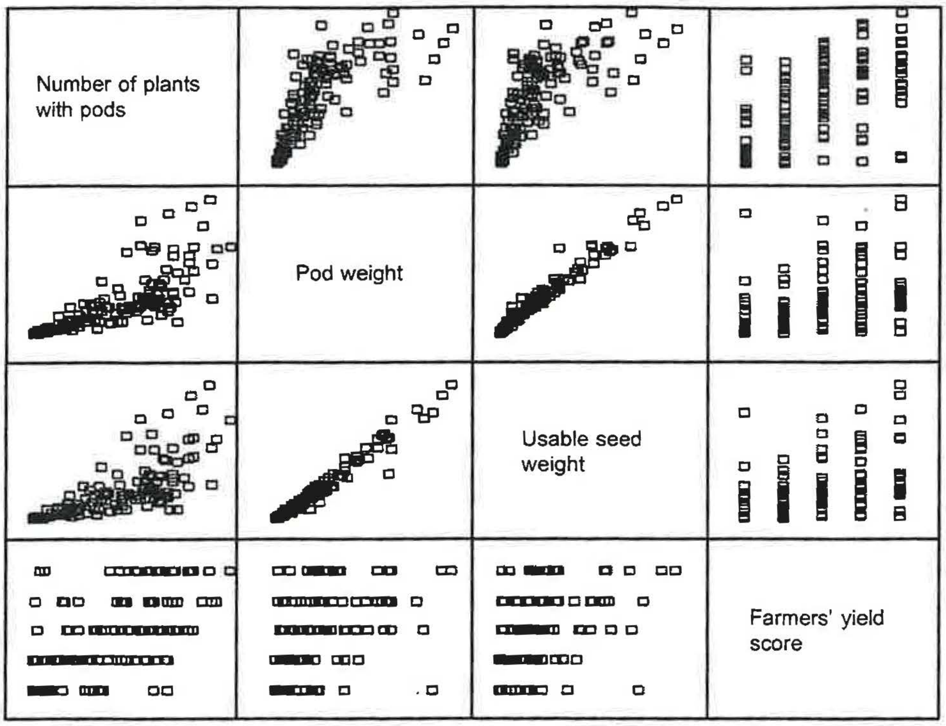

Figure 1. Beans from main intercrop trial.

what they hope to learn from the research plots. Table 6 shows that on the *kanthu nkako* plots, 67.5% of farmers were interested in comparing varieties against a range of criteria; in Table 7 participants' interest in the layout of the trial is clear. This pattern was repeated throughout the trial. (Compare, for example, Tables 30, 33, 55, 78, 88, 98, 114, 116 in the 1999 Monitoring Report.)

The *kanthu nkako* plots also allowed an objective comparison of farmer and researcher design. For example, in the 1997/98 monitoring, 60% of those interviewed had said that they would try the 90 cm plant spacing adopted by the project. Little evidence of this was seen in the *kanthu nkako* plots, as seen in Table 8. It is not fair to draw conclusions from small areas of land belonging to a subset of farmers – perhaps two-thirds of those answering the previous year's questions – however, only two out of 39 main-trial farmers had spacing above 90 cm on their *kanthu nkako* plots. This suggests that farmers remain attached to their own spacing patterns because of their desire to maximize yield (or avoid risk?).

Table 7. Farmers' learning from the research plots, main trial, post-germination monitoring

What farmers hoped to learn about	Total	Percentage
Intercropping pattern and resulting yield	20	50
Spacing of ridges and planting stations	14	35
Planting position of pigeonpea	1	2.5
New methods of farming	1	2.5
Nothing particular	1	2.5
Unable to tell	2	5
No response	1	2.5
Total	40	100

Consistency of farmer evaluations with yield measurements

The second frustration that arose with our monitoring was with discrepancies that appeared when farmer scoring and yield measurements were compared. All farmers scored each of the research varieties or pest management strategies in their trials on a number of criteria in both 1998 and 1999, and yield measurements were made on each of the plots. Hence it was possible to investigate the consistency of evaluations given by the farmer against actual yields from plots in their fields. In 1998 the project statistician plotted three yield parameters against farmers' scores: weight of usable seed (kg/ha); total pod weight (kg/ha); and number of plants with pods. (Compare, for example, Tables 30, 33, 55, 78, 88, 98, 114, 116 in the 1999 Monitoring Report.) No correlation was found for the number of plants with pods, and only a slight correlation for the other two parameters. The exercise was repeated in 1999 (see Figure 1).

Table 8. Space between maize stations in main trial *kanthu nkako* plots

Spacing (cm)	Frequency
51–60	20
61–70	4
71–80	8
81–90	3
>90	2

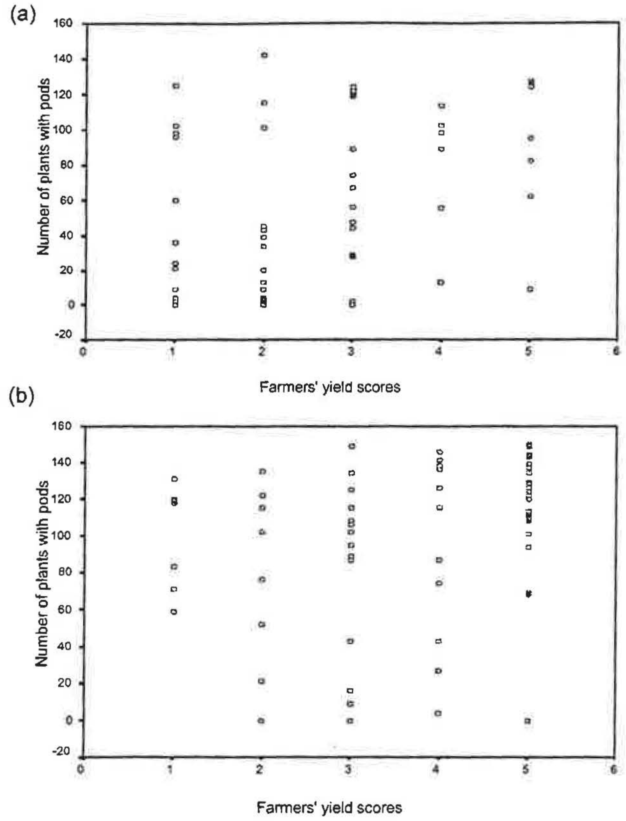

Figure 2. Relationship between researcher and farmer assessments by gender, 1997/98 bean results. (a) Males; (b) females.

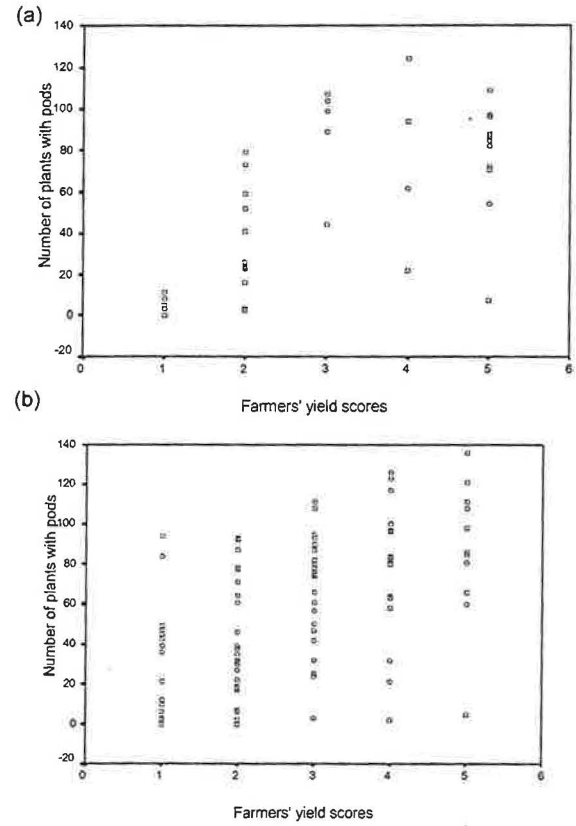

Figure 3. Relationship between researcher and farmer assessments by gender, 1998/99 bean results. (a) Males; (b) females.

Beans are used as an illustration of this problem because large groups of farmers scored beans in each season (pigeonpeas were not scored by plot in 1998). This permits a comparison over two seasons' results, and allows for the possibility of improvement in scoring technique in a second round and after a year of trials with enhanced participation. However, again in 1999 scatter plots of these parameters against farmers' evaluations for yield show only a marginal relationship for any of the yield parameters. The scatter plots show that while low scores have not generally been given for plots with very high yields, high evaluation scores appear more frequently for low-yielding plots.

The graphs were also plotted separately by EPA, but this did not lead to any improvement in consistency. We also checked the data to see if some farmers were, simply, very bad at scoring. But removing the most contradictory scores (e.g. a high score for a very low yield, or a low score for a good yield) did not result in a better relationship.

Taking pods on plants, the yield criterion most visible to farmers, the evaluations were separated by gender (Figures 2 and 3). Whereas no relationship was apparent in 1998, it seems that female farmers in 1999 were a little more precise in their judgement of yield performance for beans. Since legumes tend to fall within women's sphere of expertise, this may not be surprising. The evidence is slender but may suggest that there has been a slight improvement in scoring accuracy over the time period.

What do these results mean?

Ranking and scoring are two basic tools in participatory technology research and in participatory approaches in general. What does it mean if, over 2 years of scoring and 3 years of trials, farmers' scores do not reflect the reality of the yield results? Some researchers might suggest that this is not a real problem. Since the ultimate customer for these varieties or techniques is the smallholder farmer, what matters is what s/he thinks, not what researchers measure. Such a reply offers little cheer to agricultural scientists endeavouring to work more closely with farmers and to carry out rigorous research on varieties preferred by farmers. What other explanations might there be?

There are several possible reasons why farmers may have evaluated a bean variety more favourably than the yield result for their plots would merit. One major cause may be the low expectations that some farmers have for yield from land that has been highly exploited. Farmers who are normally unable to apply fertilizer may have been pleased with the yields they did get on the research plots, all of which had a constant application of fertilizer.

In 1997/98, a delay of up to 2 months between bean harvest and the completion of the questionnaire survey may have led to some problems with recall of actual yields experienced, and also of variety names. In addition some farmers found it difficult to distinguish between two similar varieties, Napilira and Kalima (both pink-streaked red kidney beans). Such difficulties were increased where farmers did not take part in planting.

A reluctance to criticize the FSIPM Project is likely to provide part of the explanation. Farmers mostly regard the project as a 'good thing': they receive high-quality agricultural inputs (hybrid or composite maize, fertilizer, new legume varieties) for a small plot of land in return for taking part in a range of implementation activities and evaluation sessions. If the harvest fails, for whatever reason, compensation is given to bring the yield total up to the local average level. Why discourage the researchers?

The recent experience of political oppression meant that free speech, particularly any criticism of state representatives, was often reported and punished (Dr Pauline Peters, personal communication, October, 1999). It may, therefore, have been difficult for farmers to grasp that the project sought their critical input, and that a negative evaluation of a crop would not have any unfavourable repercussions.

It is also possible that farmers suspected that the rejection of a variety might reduce the volume of inputs in following years. This possibility is supported by the fact that, in village meetings held later to discuss selection of varieties for the 1998/99 season, farmers opted to retain all four varieties for a second season. (Risk aversion through diversification of varieties would also explain this, however.)

However hard researchers try, encounters with farmers are inevitably between the resource-rich and the resource-poor. Despite the efforts of project personnel to reassure farmers that frankness is welcome, courtesy towards visitors and avoidance of open confrontation is customary. The FSIPM Project is the first of its kind in all four villages (in attempting participatory research), and local social norms may have overridden ill-understood project requests for farmers' opinions.

Problems may also have arisen with the scoring procedure used by the project in the evaluation exercise. It was perhaps too easy to fall into a pattern of awarding high- or medium-range scores. The requirement to score several times for each of at least four varieties on the basis of each of several criteria may also have led to a degree of fatigue and hence reduced attention being paid to the evaluations.

CONCLUSION

Despite a problematic conclusion to this paper, monitoring with farmers is central to participatory technology development. Otherwise, researchers work in a vacuum. Only farmers can inform scientists about farmers' preferences and criteria for technologies (whether farmers want, and are able, to apply a technology). Nor can someone from outside judge how an innovation will affect the wider farming system. Farmers also look at the research process and results from the perspective of their whole set of livelihood strategies and different household situations. Finally, monitoring and evaluation with farmers make the research process more efficient, as farmers bring their knowledge of the local environment and history of farming to bear upon a problem and help to identify locally specific adaptations.

When it comes to methods, researchers have to match their resources and objectives to the options available. Group monitoring is quick but may result in false consensus. Individual monitoring is laborious to carry out and analyse. But, at some stage, interviewing must be open-ended so that participants may spontaneously express their opinions and interests. In the FSIPM Project, open-ended questions played a part in every monitoring exercise.

Most researchers will also seek some sort of ranking or scoring to make their results internally compatible. The above analysis suggests that such exercises must be treated with caution. If possible, results should be triangulated, that is, other sources of the same information should be sought out for comparison. For example, in the FSIPM Project we are surveying farmers to see which seeds they choose to keep from the last season, and this information can be matched with scoring results.

Unexpected information can arise from monitoring: for example, farmers' enthusiasm for early maturing varieties, or the fact that we found so few farmers trying out project spacing on the *kanthu nkako* plots. Similarly, we learnt that something we regarded as relatively trivial, the plot layout, had distracted farmers from varietal performance.

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DISCUSSION

D. Coyne. Do the farmers not understand the scoring system, is it too complicated for them? Would it better to categorize according to values which they understand well? Could there also be different levels of standards between individual farmers, in which case a preliminary standardization may be required?

J. L.-M. Looking at scoring data elsewhere suggests farmers do understand the scoring system. We have a check question after a set of criteria scorings, such as 'What is your overall best variety/worst problem?' This answer is usually confirmed by top scores. Secondly, women – the least numerate and literate group – showed an improvement in their scoring on beans after the second year. Thirdly, we also associated 'word' scores – 'very poor, poor, okay, good, very good' – with these numbers. What is likely is that we may be asking farmers to score something (yield) that is not easily visible. We need to look more closely at other scoring, for example, germination scores, to test this hypothesis.

C. R. Riches. Once it was found that there was a poor match between farmers' perceptions of bean yield based on a score of pod number, and yield measured by researchers, did you then ask farmers to score yield once they had harvested?

J. L.-M. No. In the first year, 1997/98, there was too long a gap between the scoring and the harvest. In the second year, 1998/99, we did not think of doing this until it was too late. If there had been a third year, we would have done this. It was definitely a missed opportunity.

R. B. Jones. Did you ever sell 'new technologies' to farmers and then evaluate sales to see if there was an effective demand for new technologies?

J. L.-M. No, but we are carrying out a survey to see which seeds farmers have kept from the 1998/99 season. We hope to match this information with farmers' scores for the criteria listed to see if this helps explain the data better.

A. J. Sutherland. We grew different cassava varieties on farmers' plots. The varieties were not labelled. We asked farmers during field visits to rank the varieties according to preference. Then we harvested the varieties together, and asked them again to rank. Later on we cooked the varieties and farmers ranked again. The three rankings were quite different from each other, sometimes even contradictory. Men ranked differently from women. Those varieties which farmers could recognize in the field as their traditional ones were ranked highest; only when they saw the yields of other varieties did they score them lower.

Farmers' involvement in technology development: the role of farmer field schools in integrated pest management

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ABSTRACT

Five case studies, Indonesia, Zimbabwe, Kenya, Uganda and Sudan, were used to analyse the rationale behind and implementation of farmer field schools (FFS), a participatory extension approach in integrated pest management (IPM). The FFS, developed by the FAO intercountry programme in Indonesia in response to a pesticide crisis, is now being advocated in many developing countries in an attempt to actively involve farmers in IPM and crop management technology development. This study responds to an upsurge in interest in this approach in many African countries, and considers how FFS might be sustained within the extension systems of poorer countries. The case studies reveal that FFS is an experiential adult learning approach where farmers themselves discover and develop new insights and skills from agro-ecosystem analysis and group discussions. Through these processes, farmers are able to make informed decisions concerning the control of pests, diseases and general crop management which have direct implications for the improvement of their livelihoods, both socially and economically. Another facet of FFS is the level of collaboration among the three main stakeholders: farmers, researchers and extensionists. The involvement of the latter is high, but reasonable considering the significant amount of technical expertise that is required for agro-ecosystem analysis. However, the time required for FFS activities, half a day every week throughout the cropping season, may make it harder to involve poor farmers. In particular, women farmers may find this too demanding, bearing in mind their triple role of production, reproduction and community development. The approach may also be inequitable as poor farmers are likely to be missed out in a selection process that entrusts farmers to select participants from amongst themselves. The crops grown under the FFS suggest that it favours a homogeneous group of resource-rich farmers, which leads us to question the applicability of the approach to low-input systems, and confirms the generally accepted notion of differential use of technologies between men and women. As the approach is being implemented within the existing extension system, the question of continuity of technologies is important due to the differences in extension systems between Indonesia and the African countries that are adopting the FFS. The evidence suggests the potential applicability of FFS in the African context, albeit with subsequent changes in the farmer selection process, and a simplification of the approach to accommodate the needs of resource-poor farmers. An important question is whether technical support will be accessible beyond the FFS. While some conclusions are drawn from these findings, an actual field evaluation is required.

INTRODUCTION

It is estimated that nearly 25% of all the food grown in the world each year is lost to damage by insects and other pests (FAO, 1999). The battle against pests is as old as agriculture itself, and integrated pest management (IPM) has been described as "old traditional agriculture with a little bit of sophistication added" (Bull, 1982, cited by Pollard, 1991).

There is growing concern, especially in Africa, about the dramatic rise in the use of pesticides by small-scale farmers. Cases of acute poisoning and of problems with pesticide residues in local and export produce, and the cost of pesticides to farmers, have alerted professionals and practitioners in agriculture to the need to devise environmental and human-friendly methods of controlling pests (Nyambo *et al.*, 1997). While IPM is often characterized as an approach which minimizes pesticide usage, it is better viewed as an integrated approach to pest management in which pesticides are used judiciously, with the aim of reducing field crop losses from diseases and pests with minimal damage to the environment and human health. Although IPM as a concept has been around for nearly 30 years, its development and adoption in most African countries has been disappointing. Despite its many apparent benefits, IPM still does not feature in farmers' cropping systems (Lentere, 1993). This is probably because, over a long period, the strategy has been advocated in isolation from other crop management practices and there has been low effective farmer involvement.

Positive experiences of IPM in other countries which are being extended to several African countries are associated with a move towards more farmer involvement in IPM technologies and crop management in general. The FAO Intercountry IPM Programme, for example, has developed farmer field schools (FFS). The FFS training approach represents a move from conventional approaches to agricultural extension to more farmer involvement in technology development, mainly field-based, experiential learning aimed at enriching farmers' skills and confidence in decision-making about crop health (Nyambo *et al.*, 1997). There have been considerable successes in many Asian countries (such as Indonesia) in rice and vegetable cropping systems (FAO, 1999). The FFS model emerged out of a pesticide crisis in rice in Indonesia in 1986, when astonishingly high levels of insecticide-induced brown planthopper devastated over 200,000 ha of rice in central Java. The model has since been modified and successfully applied to other cropping systems including vegetables (cabbage and tomato), cotton, upland rice, irrigated rice/fish/dyke cropping, plantain/bananas, cowpeas and cassava (Youdeowei, 1999).

The FFS is now being promoted in some African countries, including Ghana and Kenya. Underpinning this approach is a holistic view of cropping systems which understands that pests and diseases are not the only field problems for farmers. In Zimbabwe, for example, the FFS is part of an integrated production and pest management approach which encourages active involvement by farmers to enable them to learn from their own actions and enhance their experimentation and decision-making skills. It is, however, important to note that FFS has been successful with high-value crops, and is usually associated with pesticide usage. This puts into question its applicability for subsistence or food crops in the African context where pesticides are not used, and pests and diseases often form only a small part of farmers' problems (Meerman *et al.*, 1997). This issue was clear from all the case studies (Ghana, Kenya, Sudan, Zimbabwe and Indonesia) used in this paper. Another facet is the time farmers are able to spare for FFS activities, which will have gender and/or social implications for different farmers.

Farmer field schools, as part of the evolutionary process in agricultural extension, are generally operated under the same system as the training and visit (T&V) approach to agricultural extension, but also draw upon farming systems research and extension (FSR&E). The T&V system has been argued to be intensive and expensive, and as such did not work in most African countries without funding from the World Bank. The most important question facing FSR&E has been how conventional agricultural scientists and extension agents would deal with their changing roles in interacting with farmers (Cornwall *et al.*, 1993). Similarly, FFS requires a significant amount of technical expertise and financial support which raises the question of its sustainability without FAO support.

Five case study areas, Kenya, Zimbabwe, Ghana, Sudan and Indonesia, were selected, based on the operation of FFS for at least 2 years. The main area of interest was Africa, but Indonesia was selected because it is where FFS first originated. This study is based on theory and examples; no actual field evaluation of FFS has yet been undertaken.

EVOLUTION OF AGRICULTURAL EXTENSION

Although much has been written about the ineffectiveness of conventional approaches to agricultural extension, some core principles have been established. One is the recognition that farmers' thinking patterns are based on concrete experience and not on the abstract ideas taught in agricultural schools (van den Ban and Hawkins, 1988). Over the years there has been a reliance on tools such as demonstration plots for farmers, which remain the core of activities in all extension approaches. Scientists have had limited regard for the conditions under which farmers need to operate for the successful adoption of technologies. This is one reason why technology diffusion in developing countries has been relatively slow.

TRAINING AND VISIT

The T&V system was developed for the World Bank in an effort to promote effective agricultural extension systems in developing countries. The T&V system centres on providing farmers with relevant, clear and sensible advice, which depends on a two-way exchange of communication contacts between farm families, extension workers, researchers and administrators (van den Ban and Hawkins, 1988). Because of its success, particularly with crops under irrigation, the T&V has been adopted in a number of countries in Asia and West and East Africa (van der Wateren and Botha, 1992). The underlying assumptions in the approach were that regular training for the field extension staff, frequent contacts with farmers and 'good' management of the extension system would lead to increased adoption of technologies. However, the requirement for intensive training for extension workers led to a preoccupation with advocating reform in terms of organization and operation in the extension system (Roberts, 1989).

What is unique to the T&V system is the degree of participation with farmers. According to Biggs (1989), whereas the conventional transfer of technology falls under the contract mode of participation, the T&V system falls under the consultative mode. Under the T&V approach farmers should be regularly and frequently visited by extension workers, with some demonstration plots mounted in farmers' fields. But while (some) farmers participated in extension activities, they had limited influence on decision-making, and planning, supply of inputs and labour and evaluation of results were all done by extension staff (e.g. Benor *et al.*, 1984). Farmers effectively served as labourers, merely following the instructions of the research or extension worker (FARM, 1999).

The approach had significant success in Turkey, India and South-East Asia (Moris, 1989). Under the sponsorship of World Bank, the T&V was advocated in East Africa. Not much thought was given to the differences between these continents in terms of the social and economic factors affecting farmers and the status of the extension system. For example, in India there had been a decade of research on high-yielding varieties of wheat and rice that were already popular among farmers, and there were also efficient input delivery systems in place (Moris, 1989). Most countries were deficient in the resources needed to warrant full application of this approach.

The diversity of extension systems has compounded this problem (Morse and Buhler, 1997). Consequently, the system has been modified in some countries to fit their specific conditions (e.g. Bagchee, 1994). Most countries implementing the T&V system were supported by the World Bank, and without the Bank's support this approach did not work. Intensive training for both extension workers and farmers requires political will from the governments. Where this has happened, there have been attempts to move extension practice towards a more collaborative type of participation similar to that advocated under the farming systems research and extension approach.

FARMING SYSTEMS RESEARCH AND EXTENSION

The farming systems approach has aimed partly to strengthen the research–extension link in order to facilitate technology adoption and diffusion, at the same time encouraging more farmer involvement. The FSR&E emerged in the late 1970s as a reaction to the prevailing extension model. Its principal argument was that constraints at the farm level limited the adoption of technologies coming from outside (Cornwall *et al.*, 1993). The FSR&E approach has therefore been based on a 'proper' understanding of the conditions under which farmers operate. Okigbo (1989) suggested that this approach facilitates not only a better understanding of the existing farming systems as a basis for their improvement, but also the development of technologies relevant to the farmers' needs and circumstances.

The FSR&E approach has been promoted as a completely new approach, whereas in reality it grew out of earlier research and extension models, incorporating the use of farmers' own fields, with farmers partly involved in the experimentation or demonstration. However, a preoccupation with implementation has dominated most agricultural research activities, and the focus has been on demonstrations, the only difference being the (probably) greater degree of farmer involvement under the FSR&E approach. There is, however, limited evidence to suggest that FSR&E has gone beyond mere farmer involvement to comparative studies with farmers. What is crucial in FSR&E is how researchers view the farmers' own experimentation. The value placed by researchers on local research will certainly shape what farmers will get out of the technology development. However, Lightfoot and Baker (1988), cited by Cornwall *et al.* (1993), point out that, due to its reliance on scientific research methods, FSR&E remains largely insensitive to farmers' knowledge, and the flow of knowledge is generally in the researcher-back-to-researcher mode. It is, therefore, unlikely that the knowledge interface between farmers and researchers has been adequately addressed.

Franzel and van Houten (1992), in an analysis of farming systems research in Ethiopia, discovered better feedback could be obtained if farmers are consulted in groups rather than individually in on-farm trials. (Farmers' groups have been involved throughout the evolution of extension: before and during the T&V approach farmers were usually organized in clubs to receive extension messages.) The FSR&E combines both group and individual farmer approaches. While the group approach is important, the size of the group and how the activities are carried out influence the effectiveness of the approach. What is crucial in these processes is the level of farmer participation. This has probably improved with the FFS approach moving towards a more collegiate mode of participation (Biggs, 1989) – at least in theory.

FARMER FIELD SCHOOLS – AN ANALYSIS

In Africa, the FFS is being promoted as a dynamic model in many different types of cropping systems. The model focuses on building on farmers' ability to experiment and to draw conclusions from experimentation. The FFS enhances these capacities by integrating training with field-based and location-specific research to provide learning opportunities for farmers/extension agents to gain the knowledge, skills and confidence (empowerment) required to make ecologically sound decisions on crop health (Akatse and James, 1999). These issues were also the driving force behind FSR&E development, the main difference being that there is more exchange of ideas between farmers and researchers in FFS. Comparative studies also allow farmers to do their own experimentation, although this largely depends on who actually controls what is to be experimented on, and how. The basic aims of the FFS are to grow a healthy crop and conserve against natural enemies by observing fields regularly and enabling farmers to become experts (Youdeowei, 1999). However, the approach is applied within the existing extension system (as with T&V and FSR&E), and the diversity of these systems is likely to affect output both across countries and even within the same country.

Elements of the farmer field school

The key feature of the FFS is weekly meetings in the fields where experiments are conducted. The main form of training is through comparative studies carried out by farmers and extension workers. Groups of farmers conduct experiments and compare results to stimulate discussion as to what would be an appropriate decision for a particular field problem. In so doing, farmers gain self-confidence and are encouraged to do more experimentation so that they become experts in research. Although farmers have been involved in experimentation through field trials under FSR&E, decisions concerning the subject and design of experiments have largely been made by researchers and extension workers. The question of how researchers perceive farmers' own experimentation and knowledge is central. Also, the trainer's ability to facilitate the process depends on acquired training and exposure which may, in the long run, affect farmers' expertise in research as well as their receptivity to new ideas.

Group work and group problem-solving and decision-making are central to FFS programmes. As reported by FARM (1999), farmers have been able to measure the yield of the experimental fields against their own yields, and to weigh up the cost of pesticides they have applied against the cost of extra time spent in the fields monitoring the situation. However, decision-making within a group is crucial, as a general consensus has to be reached. Who is able to influence such decisions depends on the composition and size of the group. It is suggested that group activities should be differentiated by gender to avoid domination by men over women, while a group size of not more than five farmers may prove efficient (farmers' groups generally vary from 13 to 25 farmers).

Extension workers in their study fields and farmers in their field schools make observations and comparisons about general crop health. This includes pests and diseases, soil, water and weeds. The field is the main venue for all activities. It is more familiar to farmers than a classroom situation, which make participants feel uncomfortable. Once farmers know what they have to do and can observe in the field, the extension worker/trainer takes a back seat, offering guidance only where appropriate. The extension worker may take part in the subsequent discussion sessions as a contributor (FARM, 1999). This contrasts with the conventional approach where extension workers assume the role of teachers. Extension workers need to be flexible in accepting their new roles as facilitators, and will need the support of their superiors.

Agro-ecosystem analysis forms the core of the weekly training curriculum. The curriculum for both trainers and farmers is integrated. Agronomy, biology, ecology, economics, sociology and education are brought together to form a holistic approach, the integrating principle being the problems encountered in the field (Entang *et al.*, 1996). This is a fundamental challenge, as trainers have to understand the basics in all these fields. In Indonesia, for example, training for trainers took 500 h. Such extended and intensive training demands considerable resources, both financial and human, requiring commitment from both researchers and extensionists, and much political will on the part of the government. With FFS, researchers' support is much more than just a foundation stone because technical support is needed almost at each level (Youdeowei, 1999). Although this would not be a problem in easily accessible areas, very remote areas would be practically difficult. What is needed in these areas is a good extension system with competent extension workers who are able to utilize their technical training.

Training covers the seasonal cycle from planting to harvesting. Monitoring the crop cycle and agro-ecosystem analysis are new to most farmers, and their inclusion highlights the knowledge gap between researchers and farmers which was not adequately addressed by FSR&E. The active involvement of farmers is likely to stimulate farmers' learning; scientists do not have to live with the results of their technologies, but farmers do (Rhoades, 1994).

The frequent meetings necessary for farmers to process the information obtained from their fields place major demands on their time. Labour and time limitations are widespread farm problems, but are often more serious for small-scale farmers (Rhoades, 1984). This is one reason why FFS have tended to work on high-value crops where farmers have been willing to spare time for the research work.

Farmer selection is a crucial component of every development programme aimed at working with farmers. Loevinsohn *et al.* (1998b) reported that FFS in Kenya used existing groups of farmers functioning for other purposes, thus avoiding the problems most projects face with farmer selection. On the other hand, the project also missed those farmers who were missed by the former criteria. In most cases those omitted are likely to be the less vocal, disadvantaged, poor, rural, women farmers who would probably benefit from these programmes. In the other four areas reviewed, farmer selection took place amongst the farmers themselves. This makes it unlikely that poor farmers who have any stigma attached to them would be selected. Selection of farmers by extension workers is equally unreliable; extension workers often end up selecting 'progressive' and innovative farmers because they spend most time with them (Biggs, 1989). It is generally believed that social pressures within the community are likely to result in selection of more prominent, wealthy, male members. In the long run it is the diffusion and continuity rate of the strategies that will show which groups have benefited. Evidence suggests that use of interest groups is less likely to include the more prominent farmers, and these groups could be useful as an entry point.

A workshop 'Towards more effective implementation of IPM in Africa' (Akatse and James, 1999) recommended that curriculum development for FFS should be done through a "workshop involving scientists/subject matter experts, trainers/extension agents and farmers as the key stakeholders to identify the constraints/issues and opportunities/options to include in Training of Trainers and FFS". From a participatory point of view, it is encouraging that farmers are involved from the planning stage; however, trade-offs are apparent. In particular, the forum might not be a favourable environment for effective farmer contributions. Information needs and modes of sharing differ between stakeholders depending on their backgrounds (Nyambo *et al.*, 1998).

One of the principles of farmer participatory research is an assumption that many farmers are actively engaged in an ongoing search for new or improved crop planting material, varieties and production techniques, and livelihood options more generally (Okali *et al.*, 1994). However, there have generally been limited efforts by research and extension to discover the elements that constitute farmers' own experimentation. This has been compounded by the limited inclusion of farmers' knowledge in field trials, even where this would have reinforced the effectiveness of experiments in their farming system. By contrast, the FFS approach has tried to make farmer experimentation central. Farmers experiment independently from their trainers (Youdewei, 1999). Loevinsohn *et al.* (1998b) demonstrate farmers' advanced capabilities in experimentation. Graduates of FFS have been observed making substantial changes in their cropping systems and, more importantly, on crops that were not discussed or experimented on in the FFS. In Zanzibar, farmers tried out rice given as food aid from Taiwan and the variety is now widely grown as a result (Fakih, 1997). Farmers' findings in Benin indicated that application of cow dung in vegetables attracts more insect pest problems (Akatse and James, 1999). Researchers clearly need to learn from these findings. Therefore FFS offer a forum where these two spheres of knowledge may be integrated.

Continuity of technologies generated under the farmer field school

Continuity of technologies largely depends on the conditions under which they are generated. The FFS approach has been successful with high-value crops such as rice, coffee and vegetables. Firstly, it is necessary to understand the relative importance of the crop to farmers in terms of economic empowerment. Farmers are likely to invest their efforts in a crop from which they know they will make a profit. Secondly, most of these crops are a drain on farmers' income in terms of pesticide use. The savings arising from reduced pesticide use will attract most farmers as long as the IPM intervention demonstrates as effective control as pesticide usage (Goodwell, 1984, cited by Pollard, 1991). Thirdly, what is seen as a solution depends on what is perceived to be a problem. This implies that there is likely to be spontaneous adoption if technologies respond to farmers' problems. However, technologies may not survive in the African context if they are based on the 'fix-all principles' of FFS rather than what can feasibly work in a specific locality. What works in Asia may not necessarily work in Africa, and even within Africa there are differences. Since FFS are being implemented within the framework of the existing extension system, countries need to work out which aspects fit well into their system before thinking of scaling-up the approach. The current upsurge of interest and enthusiasm for implementing FFS means that there is a danger of copying successful countries without due consideration of these differences.

A further dimension to continuity is the active dissemination of experience gained in the FFS. Farmers' ability to continue applying the principles and skills learned in the FFS may motivate them to teach other farmers and thus speed up the dissemination process. Farmers' ownership of new skills, knowledge and technologies provides opportunities for horizontal sharing of opportunities through farmer–farmer interaction, for example, by influence on relatives and friends (Loevinsohn *et al.*, 1998b). Such dissemination reveals networks through which technology transfer might take place, and success will reveal which technologies are acceptable to most farmers. Since participants in FFS are a limited subset of potential beneficiaries (Okali *et al.*, 1994), farmer–farmer interaction is likely to favour the extension of results to a wider community.

The potential to sustain the FFS is, therefore, based on this wider interaction between farmers and researchers and among farmers themselves. Constant efforts are, therefore, needed to simplify the approach, to bring it within the reach of the majority of poor farmers. In Kenya and Indonesia, the pilot FFS were conducted in the trainers' own districts, with implications regarding communication and trust between the two sides. The same approach is applied in Indonesia, where farmer graduates are used as trainers in new FFS. This has probably contributed to the considerable successes of FFS, but also offers the hope of life beyond FFS, because such farmers will stay in the area and perpetuate the approach if they find it affordable.

Gender disparities in farmer field schools

There is a general lack of attention to women's needs within the development process, stemming from a lack of awareness amongst those who plan and implement development programmes. The fact that women account for 70–80% of household food production in sub-Saharan Africa (Saito, 1992), and that women's work is at the core of developing countries' economies (Dixon, 1982, cited by Gabriel, 1990), is evidence that gender blindness is likely to hinder many development programmes. "Africa is a region of women farmers par excellence" (Boserup, 1987, cited by Pearson, 1992). This means that for any successful farming experiment, women should form a central component. Gender analysis has been partially incorporated into some methodologies such as FSR&E and participatory research analysis (Longwe, 1991). In IPM, few mechanisms exist at either national or international level to incorporate gender issues into research and development (NRI, 1992). Unfortunately, there seems to be little interest in developing appropriate technologies that will suit the needs of women farmers (van der Wateren and Botha, 1992). The extent to which FFS are able to incorporate gender issues forms an important basis for successful technology development, and such efforts are necessary right from the initial stages. The division of labour, in terms of what men and women do, offers insight as to who is likely to benefit from the FFS. This directly translates to who effectively does what in agricultural production, and who is actually involved in the activities of FFS. It is generally accepted that women carry out the larger part of crop management activities (here 'women farmers' is used to apply to all women carrying out agricultural activities, whether in female-headed or male-headed households). Women carry out the majority of pest management activities and are mainly responsible for weeding, especially in Africa (NRI, 1992). The Kenyan example shows that women farmers are unlikely to make decisions related to coffee management because it is perceived to be a 'male' crop (Loevinsohn *et al.*, 1998a), despite the fact that women have been shown to be more efficient managers than men (Saito, 1992). Interestingly, women's management skills in coffee production were improved after attending FFS (Loevinsohn *et al.*, 1998a), which implies that the women received the knowledge they needed. However, attention to farmer selection may reveal power structures within the village that might influence who is selected to attend FFS. The challenge, therefore, is how to incorporate women's needs to make FFS more accessible by women.

The other gender consideration relates to the organization of the FFS in terms of the time spent in the field throughout the cropping season. Farmers meet once a week for at least half a day (FAO, 1999), which means a total of 16 weeks. It is likely to be problematic for most women to participate effectively in FFS for the whole cropping season. The 'triple roles' many fulfil are already a constraint on time and energy. Women are severely constrained by the burden of simultaneously balancing the roles of reproduction, productive and community management work (Moser, 1991). For most households, domestic work is a fundamental component of provisioning and consumption (Crehan, 1992) which is mostly the responsibility of women. Most importantly, for the majority of poor rural women, life is primarily directed towards survival strategies for themselves and their dependants (Johnson, 1992), so women are likely to prioritize survival activities over any other activity. It is, therefore, justifiable to argue that the technological needs of women are distinct from those of men, that is, they need low-external-input and time-saving technologies. This suggests that strategies that are time-consuming are likely to miss out women as a gender. This is likely to be the case if FFS continue to operate as they currently do and, inevitably, both adoption and continuity rate will be affected. The impact of training and observation after the FFS is particularly important as there is an uneven diffusion of strategies between men and women, with men diffusing to men and women to women (Loevinsohn *et al.*, 1998a).

Considering the complex nature of the FFS (agro-ecological analysis, data collection and interpretation), women farmers may find it particularly challenging because of their level of education. More women than men lack basic education as a result of household decisions to educate boys, cultural influences, and a school environment that favours education for boys (F. Ellis, School of Development Studies, University of East Anglia, 1999, personal communication). Technical skills training in agriculture as part of informal educational activities has largely benefited men more than women (Lind, 1990). This is partly because women may not participate in the wider institutions of society in the same way as men, because they are less educated. While the use of diagrams may be helpful in increasing the women's understanding, care should be taken in the use of more complex diagrams. These may necessitate further elaboration and careful attention to how well women farmers understand them. Such care will depend on whether scientists and extension workers perceive this to be a problem.

Groups have their own gender identities. Women are generally less vocal in mixed groups, which is likely to impair their input into the activities of the FFS. Lawson-McDowall and Kapulula (1999) noted that men perceived women's silence in groups or clubs as due to a lack of interest in group participation, while women said they were disadvantaged because they were shy. Considering that local knowledge possessed by men and women may be different (Malena, 1994, cited by Morse and Buhler, 1997), heterogeneous groups effectively mean more limited exploitation of women's knowledge, which could play an important role in developing viable strategies. While farmers' groups are fundamental to the FFS, it is important to consider smaller, homogeneous groups that may work better and more efficiently, and may continue to interact in future.

Crops grown under farmer field schools

In Sudan, the FFS focused initially on cotton (a crop which has suffered catastrophic consequences of over-reliance on pesticides), then in 1993 the focus shifted to vegetables (FAO, 1999). In Indonesia, the main focus of IPM/FFS has been on lowland rice, after observing that pests were increasingly becoming resistant to pesticides. Upland farmers are now being involved in sweet potato IPM (Braun *et al.*, 1996). The main focus of the Kenyan FFS has been on coffee (Loevinsohn *et al.*, 1998b), while in Ghana it is rice (Youdeowei, 1999). Zimbabwe's FFS activities have centred on cotton (Zimbabwe, 1999).

It is generally true that in the African context such crops are grown by resource-rich farmers because they require high-input systems (fertilizer and pesticides) which most resource-poor farmers are unlikely to be able to afford. Again, the crops are usually monocultures (less complex ecosystems) that are only suitable for those with significant amounts of land. Peters (1993) observed that only few women with sufficient energy, skill, land and access to cash could continue to grow a high-value crop, burley tobacco, in addition to their maize. The high-value nature of the crops, therefore, justifies the farmers' ability to spare time for FFS activities. This also has important implications as to whether the small-scale farmer would perceive FFS activities as equally important. Would FFS activities for low-value crops be equally useful and worth sparing time for? It is probably ambitious at this point to claim that FFS are targeting poor farmers, until they have become attuned to low-input systems which are usually complex.

Debates about rural livelihoods

All the thinking behind FFS suggests that the farmer should be productive in his farming and achieve a better livelihood from it. The question of how a farmer's involvement in the activities of FFS affects the farmer's livelihood and well-being is central. The FFS aim to go beyond passing messages to farmers, to placing principles and concepts at their disposal, and thus empowering them. The farmers' ability to make informed decisions in pest and crop management is a move towards sustainable livelihoods, with savings in costs and avoidable illness due to pesticide poisoning, and increased crop yields.

A study in Indonesia showed that 21% of spraying operations resulted in three or more symptoms associated with pesticide poisoning, and 84% of farmers were also found to be storing chemicals in their homes, in unsafe conditions where children could reach them (Kishi *et al.*, 1995). In African countries most smallholder farmers do not wear protective clothing. With reduced exposure to pesticides, farmers will be physically able to perform optimally in their farming and other economic activities (Namibia, 1999), thus saving time lost due to illness. This will also save the farmer money on health care.

Injudicious application of pesticides poses high risks not only to the farmer himself, but also to the community that uses his product. This is particularly the case with much vegetable production, such as cabbage and tomato. Evidence shows that most farmers apply pesticides routinely (Wijeratne *et al.*, 1993, cited by Wijeratne and Abeydeera, 1996), sometimes just for insurance because vegetables are highly marketable. Farmers' capacity to determine the right time to apply pesticide following participation in FFS is very promising, and will have important effects for the general development of the community.

It is unlikely that most farmers know the effects some pesticides can have on their animals, apart from poisoning. Neshein (1999) reveals the effect some chemicals can have on the fertility or reproductive rates of animals, both males and females. Where pesticides are used intensively and with little care, livestock, a very important asset for most small-scale farmers, are likely to be affected although farmers may not be aware of this. The economic empowerment resulting from reduced pesticide usage may encourage more investment, perhaps in children's education, or in other important household assets that provide a safety net in times of shock.

Most striking in the FFS approach is a holistic approach to technology development. All field problems are observed and dealt with (subject to availability of technical support). Soil fertility is one of the most important problems facing farmers in many developing countries, and addressing this problem has been crucial in some FFS. In the Philippines, for example, the FFS have been centred on integrated soil management techniques (FARM, 1999). Loevinsohn *et al.* (1998a) reported that women graduates in Kenya have improved their decision-making influence within the household in relation to coffee, traditionally a man's crop. The enhancement of farmers' capabilities to make crop management decisions for one crop is likely to extend to other crops if the farmer finds it worthwhile. The capacity to make informed decisions in IPM and other crop management activities is an important development for farmers' livelihoods. Farmers in Indonesia have moved a step towards the development of community IPM that promotes healthy farming in the community (FARM, 1999). This is encouraging given that pests are migratory and do not observe field boundaries. This has become possible because the FFS groups have been functioning since 1986, mainly on rice. And apart from development related to IPM, farmers may also be able to organize themselves into other development-related work, or may find themselves able to influence the activities of their community for the benefit of all.

CONCLUSION

The discussions above suggest that FFS have the potential to improve rural people's livelihoods by empowering them to grow a healthy crop, use low levels of pesticide in a safe environment, and make informed decisions in order to lead a healthy life. The basic elements of FFS (field-based, agro-ecosystem analysis, group problem-solving, adult learning approach) are fundamental to the success of this approach in Africa. The level of farmers' involvement in the whole process is particularly encouraging.

However, gender blindness appears widespread. Evidence for this includes the time farmers are required to spend in the FFS, the selection process, and the heterogeneity of groups which offer limited opportunities for women farmers. Poor farmers may also be less able to spare time for FFS activities because they generally use their labour and time to suffice their basic needs.

FFS is theoretically 'new', but in practice is part of an evolutionary process, effectively operating under the same conditions as conventional approaches (a fusion of T&V and FSR&E), where success is partially dependent on financial support. All the locations reviewed here have received financial support of one kind or another. The T&V and FSR&E have all worked in the specific contexts of resource-rich farmers, high-value crops and less complex ecosystems, which inevitably pushes out poor farmers (most of whom are likely to be women). This brings into question the applicability of the approach for low-value crops. FFS are also implemented within the extension system, so these issues are of relevance. Related to this is the support that researchers are willing to give to extension, bearing in mind that FFS require a great deal of technical expertise, and the role of extension workers as facilitators deserves more attention. However, it is not clear whether technical support will be available beyond FFS.

- While the FFS approach is being widely implemented, it is important that more thinking is devoted to its simplification to make it more user-friendly, at the same time looking at sustainability within the extension system. Otherwise, effort and money are likely to be wasted.
- The simplification of the FFS will make the approach more user-friendly, especially for resource-poor farmers who are generally time and labour constrained.
- The current farmer selection process disadvantages less vocal and poor farmers particularly women. There is a need to revisit it.
- There is a need for actual field evaluation of FFS by practitioners in the development arena other than those actively involved in FFS.

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DISCUSSION

C. Chanza. In most African countries extension services vary from one country to another. Hence one extension model may work in one situation but not in another. To what extent do you think lessons learnt from your study will be applicable and generalizable to Malawi?

C. K. This is what provoked my curiosity to find out the conditions under which FFS have been introduced and implemented. FFS in Malawi cannot be based on the diverse extension systems of other countries using the same approach. Indonesia, for example, where FFS were developed, has a well developed extension system, and the system in Kenya is better than that in Malawi. This means that Malawi needs to work out what can feasibly fit its system and not just copy from other successful countries.

B. Msiska. You seem to advocate homogeneous FFS. Have you made any observations regarding the performance of homogeneous female versus male FFS compared to heterogeneous FFS?

C. K. No. The performance of homogeneous groups was not discussed in the case studies but this would be an interesting issue to investigate in field evaluations.

C. Chibwana. According to my experience, the issue of mixed versus homogeneous groups varies according to the culture and religion of the farmers. In some cases, mixed groups work, while in others they do not. Rather than make a blanket recommendation, my experience in working with women in the Women's Programme of the Extension Department showed that the decision is best left to the farmers themselves. The extension worker should encourage farmers to discuss the subject and tell them the two options. Farmers then make choices depending on their particular situation.

M. M. Kayembe. Most projects in Malawi aim at improving the livelihood of the massive rural poor by technology transfer through participatory approaches. But looking at the spectrum of rural poor, most avoid taking risks in adopting technology and always shy away from involvement in group meetings. Only the well-off farmers present themselves in these meetings. Therefore, technology transfer requires a simple, modified approach even in farmer schools in order to be effective in involving the rural poor.

Innovation in agriculture: networks of communication among project farmers

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ABSTRACT

Knowledge and skills are crucial human resources for successful agriculture. The means by which farmers gain and exchange information about new agricultural practices and technologies are an integral part of any farming system. Formal and informal networks of communication vary from place to place in their constitution and effectiveness. A study was conducted in the four villages where the Farming Systems Integrated Pest Management (FSIPM) Project has been working since 1996 to determine the status of existing formal and informal networks of communication and their potential utilization in the dissemination of IPM strategies. Smallholder farmers in the on-farm trials took part in group discussions to explore their views on the current state of extension services and on informal means of communicating agricultural messages. Local extension workers and a senior officer at extension headquarters were interviewed. It emerged that subsistence smallholder farmers in these areas have either limited or no contact with the formal extension services. Radio alone plays a useful role in dissemination. Information about agricultural innovations also comes through friends and relatives, from farmers' own experimentation and from observation of other peoples' fields, but these sources are limited in their effectiveness. Farmers stated that they need frequent group meetings with extension workers to have direct contact with someone who understands local agricultural problems. By contrast, the extension officers had found that farmers have no interest in meetings or training unless they are also able to access input and credit packages. All agreed that the extension services were currently in decline and that farmers had been better served in earlier years.

INTRODUCTION

This paper focuses on learning about innovation in agricultural technology and practice and explores how, in four villages of southern Malawi, farmers meet their need for knowledge about agricultural innovations. The topic is of particular interest to the Farming Systems Integrated Pest Management (FSIPM) Project as it is attempting, with the participation of selected farmers in these villages, to develop a set of integrated pest and crop management technologies that will, in due course, be suitable for dissemination elsewhere in the area. In order to lay the groundwork for this process, it is necessary to understand how information is sought and received in order to assess which routes and media will best reach the resource-poor farmers who constitute the target group for the work of the project.

The project and study region

The FSIPM Project has been working since 1996 in Chiradzulu North (Mombezi) and Matapwata Extension Planning Areas (EPAs) of the Blantyre/Shire Highlands Rural Development Project (RDP). The staple cereal of the area is maize. Maize is intercropped with pigeonpea (*Cajanus cajan*), beans (*Phaseolus* spp.) and a variety of other legumes, tubers and vegetables. This maize ecology is representative of 40% of the area planted to maize in Malawi (Heisey and Smale, 1995, cited by Orr and Koloko, 1998). Low average yields (836 kg/ha for local varieties and 1765 kg/ha for hybrid semi-flint varieties) reflect poor soil fertility and low use of inorganic fertilizer. The main cash crops are burley tobacco and *dimba* garden vegetables (grown for the markets of Blantyre and Limbe), although all crops are marketed to some extent. Sixty per cent of land holdings in this area are under 0.5 ha. Women head 38% of households in the RDP. (See Orr and Koloko, 1998.)

The project's objective is to improve the welfare of poor farm families by reducing crop losses from pests, weeds and diseases. Participatory research methods are used to develop appropriate pest management strategies, sustainable within the constraints of the smallholder farming systems, to reduce crop losses (ODA/GOM, 1995). In order to ensure that these constraints are recognized, it has been a priority of the FSIPM Project to understand the farming system as a whole.

Rationale for research

The original rationale for this research is specified in the Project Memorandum:

> "The ... social anthropologist ... will study the formal and informal communication networks between farmers and between villages and the way they are structured by gender, ethnic group and socio-economic status. This information will be used to assess the capability of utilizing existing traditional net-

works to spread the knowledge of project activities, findings and recommendations and to develop low-cost methods for improving access to information for the different categories of farmers."

(ODA/GOM, 1995)

As the project continues, there have been seen to be benefits to be gained from looking at communication networks beyond assessing capability. How farmers learn is a dimension of the farming system about which little has been learned through other project activities. This study therefore complements other project work by extending our understanding of smallholder farming systems in the target area.

KNOWLEDGE AND THE FARMING SYSTEM

What is the role of information networks in the farming system?

"Farmers' capacity to control their environment is the result of the resources at their disposal; among these, knowledge and skills are key components. In order to understand a farming system, it is just as important to understand its communication networks as it is to understand its environmental situation or changes in its market place."

(Ramirez, 1997)

Farmers in any agricultural system must respond to changing circumstances, whether alterations in their natural or human capital endowment, market opportunities, the introduction of new inputs and technologies, or the broader policy environment. In order to do so, they need information: individuals "interact constantly, seeking to negotiate and create opportunities to fulfil their needs and pursue their interests" (Ramirez, 1997). These patterns of communication and information exchange make up an agricultural knowledge and information system which is an integral part of the broader farming system. Since such systems or networks are dynamic and derived from multiple sources within and outside rural society, innovation will be enhanced or impeded by how efficiently the information is picked up by, and moves between the individuals who make up the strands of the net (Reijntjes *et al.*, 1992; Ramirez, 1997; Warburton and Martin, 1998). (Innovation may, of course, be impeded in other ways, for example, by lack of resources: farmers who cannot afford new varieties do not try them out.)

Networks of communication have both formal and informal elements. In developing countries, formal networks of communication are generally considered to be those originating from government institutions such as the agricultural extension service, its agents, publications, posters and radio broadcasts, but also material or activities produced or organized by NGOs, relevant industries, marketing boards and donor projects. Informal networks of communication are, effectively, anything else: communication between farmers, through traditional societies, between farmers and traders. A final source of information that is considered here is learning through one's own or another's observation or experimentation. Access to information through both formal and informal means may be differentiated according to gender, age, ethnic group, education and socio-economic status.

"Knowledge and access to knowledge are not spread evenly through a community: people have differing objectives, interests, perceptions, beliefs and access to information and resources. Knowledge is generated and transmitted through their interactions within specific social and agro-ecological contexts."

(Warburton and Martin, 1998)

There are examples from elsewhere of categories of knowledge being "tied to economic or cultural roles within the community" (Reijntjes *et al.*, 1992). Men and women may have knowledge of different crops or different agricultural activities. It should not, however, be taken for granted that knowledge is differentiated in this way in every context.

The data presented here are from a study conducted in the four villages where the FSIPM Project has been working since 1996. Smallholder farmers in the on-farm trials joined in group discussions to explore their views on the current state of extension services and on informal means of communication of agricultural messages. The field work took the form of two rounds of focus group discussions in September/October 1998 in the four target villages. Focus groups were chosen in preference to individual interviews in order to generate information about common experience. Where there are disagreements, it was possible to explore the reasons why and to see what this reveals of differences in situations or requirements. In each village, men and women met separately to ensure that each group was able to express their views freely and to see if there was any difference in access to information due to gender. The groups were limited to a maximum of 10 members in order to encourage all members to take part. The meetings took place in two rounds so that information from the first set of meetings could be analysed before being re-presented to farmers for basic ranking and scoring. Local extension workers and a senior officer at extension headquarters were interviewed to see how they viewed the current situation. The distinction between formal and informal in the context of this research should not be exaggerated. The formal components consist of two Field Assistants (FAs), the radio, a few pamphlets, magazines and posters.

FINDINGS

Scoring and ranking

Participants were asked to score sources of information about agriculture. The scoring data are presented in Table 1.

Men and women agreed on the importance of the wireless and of friends as sources of information about agriculture. There was also a consensus that it is not so easy to learn from one's own experimentation.

However, men and women disagreed about the usefulness of the local extension services. Men and women gave the extension worker respective scores of 4 and 1.8. (This result contradicts both men's and women's groups' assertions – discussed below – that there is no discrimination between men and women when it comes to access to the extension officer.) Men also rated written extension material more

Table 1. Comparison of scores by men and women

Scoring	Women	Men
Radio	3.7	4.3
Friends	3	4.3
Written material	2.7	3.3
Extension worker	1.8	4
Own experimentation	1.8	1.7
Other places	1.5	4

highly than women, giving a score of 3.3 whereas the women scored this at 2.7. Finally, superior male mobility is reflected in a high male score of 4 for learning from other places compared to women's 1.5. This result was qualified by men in Kambuwa who pointed out that it is not possible to learn much from places with very different climatic conditions. Women in Magomero took the discussion back to the extension services by suggesting that the best places to learn from are those where the FA is working.

Overall, men consistently gave higher scores than women to most sources of information. The differences are supported by the group discussions below. Men are more likely to own radios and have time to listen to programmes; they are more likely to be able to read, so can make use of written material. Similarly, men have greater access to the extension worker through the crops they grow or the clubs they join, and are more likely to visit other places where they have opportunities to compare agricultural practices.

The radio was generally agreed by farmers to be a good source of information, but not one that could stand alone. Access to radios is patchy, many farmers do not own a radio or if they do, they may not be able to afford to 'run' it all the time. Respondents were asked how many radios and how many households there were in the cluster of related households where they lived (the *mbumba*). Out of 125 households, 76 (61%) owned radios. It was generally agreed that radios were mostly bought and owned by men as they were more likely than women to earn sufficient cash. The men's group in Chiwinja was the exception, in that they said radios were for the use of the whole household so should be seen as a household asset. Regarding access, the groups in Magomero, women in Chiwinja and men in Lidala thought that men spent more time listening than women. Women in Magomero said that men even carried their radios around with them so that they could listen as they travelled or worked (the 'Malawian Walkman'). The men's and women's groups in Kambuwa said that they thought women had greater access to the radio since men tended to be out at work while women stayed at home where they could listen to the radio. Nonetheless, the current reach of radio compared to other

Table 2. How farmers learn: sources of information, their advantages and disadvantages

Medium of communication	Advantages	Disadvantages
Radio	Available Professional extension messages People listen to the radio a lot Do not have to stop working to listen Cheap for extensionist	Not always convenient Expensive to run and maintain People listen casually Can't ask questions Possible gender bias, owned by men
Extension services (block meetings, extension officers)	Trained adviser Face-to-face contact Can ask questions Group meetings with fellow farmers Demonstration plots Source credit and training for particular crops Extensionist has authority to train and teach	System in crisis (80% did not attend block meetings, 60% had never seen a demonstration plot; BLADD, 1993) Low coverage of households Better-off farmers targeted, means female-headed households excluded Excludes those not interested in specialist crops
Written material	Can combine words, pictures and diagrams very effectively Farmer can study as long as likes, can consult whenever necessary	High illiteracy rates (women 85%, men 57%; Pryor 1998) Expensive to print and distribute People hoard rather than share
Own experimentation	Working under own conditions Determined by farmer interests and needs	Results are uncertain Resources very limited Need for food security may interfere if experiment fails
Learning from friends	Face similar sets of problems or constraints Trust each other's recommendations	Limited knowledge pool Fear of sharing incorrect information
Learning from wider community	Face similar sets of problems or constraints Information spreads more quickly	Fear of jealousy, of witchcraft if 'too' interested in others' fields Fear of being thought proud or boastful (setting up as a 'teacher')

means of extension means that there is a strong case for considering radio as a medium for project crop and pest management technologies. However, the nature of radio means that reinforcement of the message in the form of extension advice or written materials is needed.

We were surprised by the enthusiasm for written materials, given the low levels of literacy found in southern Malawi (Pryor, 1988, suggests 85% for women and 57% for men). Both men and women farmers in the discussion groups were keen to see more Chichewa language pamphlets. When asked how the illiterate might benefit from written extension materials, participants said that this was not a problem, "If the parents cannot read, then their children can read and translate information for them." It is understandable that extension officers would like to have pamphlets and booklets to hand out to interested farmers, but it seems less likely that many farmers would be able to make proper use of this information. The project plans to produce written material in both poster and pamphlet form, in co-operation with the government extension communications section. Attempts should be made to identify other research that would help us to assess this enthusiasm against actual coverage achieved by written materials. Such information might be available from Ministry headquarters and also from other organizations working in agricultural extension.

An overall summary of the different sources of information available to farmers, their advantages and disadvantages, is given in Table 2.

Farmers' own experimentation

Participants in all four villages said that some of the agricultural activities they practise were discovered by farmers themselves while trying to solve problems. Successful results can then be seen by family, neighbours and passers-by, or be passed on to others. One example of local experimentation, the result of which has now been shared widely, is the eradication of difficult weeds such as *kapinga* (*Cynodon dactylon*) by digging deep into the ground, removing the weeds, drying and burning them away from the field.

Men in Kambuwa and Magomero said that the trouble with trying to discover things by yourself is how to be sure whether something has really been proven. One participant said "trying something out for oneself is just a game of chance". These comments suggest that at least some farmers are aware of the limitations of their own experimentation, and would be open to suggestions for improvement. Participants explained that this difficulty in knowing something for sure means that it is hard to persuade a friend of genuine innovation. However, the men's group in Chiwinja disagreed with this view, and said that friends are very useful when experimenting precisely because they can help you confirm whether or not you have learnt something new.

Discussions with other farmers about experiences, experimentation and observations, both on site and elsewhere, were acknowledged by the majority of participants as a source of knowledge, but one limited in usefulness. Participants stressed the importance of similar situations: if something works for a friend, it may work for you too.

In the second round we were keen to clarify further who 'friends' were and whether there were any barriers to communication. The groups said that they would only talk to close and trusted relatives and friends about agricultural problems or innovations. Interestingly, traders and shops were not mentioned as a source of information. The importance of kin over friends was stressed, for example, women in Lidala said they would share information with a relative before a friend. Friends are people who you have known for a long time, who you visit and chat with (*kucheza*), who give you good advice or help when there is a problem. This is likely to be someone who is a neighbour, or who works in a neighbouring field, or a fellow member of an organization such as a church or agricultural club. Women said that they often chatted at the borehole. Men in Chiwinja said that something useful heard on the radio would be shared within the family but not outside the family group. Even amongst kin and friends, it was pointed out, not everyone is interested or open-minded enough to want to learn new things. Among other problems encountered when learning from friends are that they may not remember all the details of something they have been taught or have heard.

Women's groups in Chiwinja and Magomero emphasized how important it is to be careful when asking someone about what they are doing in their fields, or when sharing information about your own field. Many villagers would suspect theft or witchcraft. In Kambuwa the women said that they do not talk to fellow villagers who mocked them at the start of the project and taunted them that the foreigners would steal their land. It is, however, quite acceptable to discuss agricultural successes or problems with outsiders with a legitimate interest such as the FSIPM Project or the FA. Women in Lidala said that they found it easier to trust people from outside the village as they were less likely to steal crops.

In general, there is a prohibition on looking at others' fields which limits flows of information between those not well acquainted. Farmers fear to have crops stolen or bewitched (*kukawa*, a term applied specifically to a loss or mysterious reduction in yield at the time of harvest; or *kupininga*, a more general term for the casting of spells or of being suspected of having evil intentions towards another's crop). Even relatives may cast spells. Many protect their fields with charms to prevent this sort of damage. The men's group in Kambuwa told us that FSIPM Project members should be careful not to inspect fields where there are no plots lest their interest be suspect.

Farmers also detailed what sorts of issues they might ask others about. People are keen to talk to a person whose field is doing particularly well that season, to find out why this is and how the farmer came by the idea for the technique or the technology. Women in Magomero said that they might seek advice about *dimba* agriculture (vegetable growing), a relatively new enterprise and one dominated by men, but that for upland agriculture (maize and the various intercrops of the maize system) people tended to work alone. This 'ordinary farming' should be familiar,

Table 3. The content of extension messages in Mombezi and Matapwata EPAs

Crop	Issue	Recommendation	Area
Maize	Fertilizer application	Basal dressing 35:10:0 + 2s top dressing 69:21:0 + 4s	Mombezi
Maize	Pests (grasshoppers, caterpillar, aphids, armyworm)	Hand picking, spraying	Mombezi
Maize	Spacing	90 cm between planting stations	Matapwata
Maize, pigeonpea, sorghum	Low yields / late maturity	Plant hybrids	Matapwata
Burley tobacco	Pests (grasshopper nymphs)	Spraying, field hygiene, hand picking	Mombezi
Beans	Pests (beetles, caterpillars)	Killing manually, spraying	Mombezi
All crops	Low fertility / lack of land	Intercropping	Matapwata
All crops	Soil erosion	'A-frame' on water entry points	Matapwata

so asking questions looks foolish. The women went on to say that with 'ordinary farming' there would only be discussion about very general issues such as whether there had been enough rain to plant or not, or how well a new seed was doing. This is not encouraging news for a project concentrating on 'ordinary' crops.

The role of the extension services

During the discussions, all agreed that the extension services were in decline and that farmers had been better served in earlier years. A survey carried out by Blantyre Agricultural Development Division (BLADD, 1993) found, however, that there was less contact between farmers and extension workers under the Block Extension system now practised than under the Training and Visit system, and that this was resulting in poor dissemination of extension messages. Results showed that around 80% of farmers did not attend block meetings and 60% had never attended or viewed an on-farm demonstration. The report also queried the content of extension messages as unsuitable for farmers with land holdings below 1 ha and for resource-poor households including poor, female-headed households. These two categories of farmers form the majority in the area (BLADD, 1993). The report recommended further development of on-farm demonstration plots with more relevant material. The FAs confirmed that there are no functioning block committees, plots or meetings in any of the villages. The block centre in Lidala has been inactive since 1993, and an unresolved conflict between Chiwinja and another village as to the site of the block plot meant that the project was abandoned. Both Magomero and Kambuwa should have block plots and committees, but do not.

The role of the field assistant

The FAs cannot be blamed for these problems. Their work schedule is quite unrealistic: they cover about 2000 farming households over a large area where communications are poor, particularly during the rainy season. One of the two men is only a caretaker and covers two areas. They are supposed to run 300 demonstration plots, to co-ordinate credit and training clubs for maize, burley, chilli peppers, groundnut seed multiplication, vegetable growing (amongst others), and the new fertilizer clubs (APIP and the Mudzi windows). All this without suitable equipment or transport and for what they consider a pitiful salary.

The FAs told us that, in their opinion, farmers are not interested in coming to group meetings unless there is a chance to get inputs and credits. Most farmers feel that they already know how to do the 'basic' farming of food crops and say their greatest need is for inputs. The FAs blamed local leadership for not encouraging farmers to take more interest in the block system. There were also some problems with the structure of the block demonstrations. If the land was provided from common land by the chief, then inputs and labour were donated by the group and profits from the produce went to the group or into the club account. If the land was donated by an individual farmer, even if inputs and labour were provided by a group, he or she (usually he) kept the produce. Overall, the demonstration plots are not very successful because the farmer concerned regards the plot as the property of the FA rather than as his own enterprise. As a result, the two FAs found that farmers worked on their other plots and neglected the demonstration plot unless closely supervised by the extension officer. The FSIPM Project has encountered similar attitudes regarding ownership of the trials among some participants. (This offers yet another explanation for some of the difficulties we faced in setting up the FSIPM trials.)

Nonetheless, the evidence presented here suggests that extension work at present in these villages is only reaching a small percentage of better-off male smallholder farmers who are members of specialist crop clubs such as burley tobacco or chilli clubs. In 1998/99, the Mudzi window initiatives to provide 0.2 ha worth of maize and legume inputs to trained groups of either men or women appeared to be spreading credit more widely. Our impression was that better-off and well connected households (with social capital) dominated the membership. While precise statistics are unavailable, Peters (1993) states that there were 'extremely few' female members of burley clubs. Those smallholder farmers who are not growing the cash crops targeted by the extension services appear to have little or no contact with farmers.

Relevance of extension messages

There also appear to be problems with the relevance of various extension messages being put out by the FAs (Table 3).

Much of this material is insensitive to the heterogeneity of the rural population in terms of their access to human and economic resources. Where farmers actually receive advice, it is to buy and apply relatively large amounts of fertilizer, to use pesticides, to plant high-yielding hybrid seeds and to intercrop many different crops, all of which require substantial investments of cash. Those recommendations that do not demand a financial outlay oblige the farmer to find extra time for activities such as hand-killing pests during the peak work period. This advice favours those households with substantial endowments of capital and labour rather than the resource-poor.

Farmers blame the extension services for a lack of commitment to smallholder farmers and, in return, extension staff attribute the problem to farmers' lack of interest in anything other than credit or input packages. Certainly, most members of the focus group discussions took the opportunity to remind team members that their most pressing need is for credit for fertilizer. The most cheering note is that both farmers and extension officers agree that the solution to their problem is group meetings for training, supported by written material. Whether farmers would attend without the incentive of a credit package, as in the days of the maize clubs, is not so clear.

Farmers said they thought there was little difference between men and women in their access to new information about agriculture. While this may be true of the informal networks of communication, farmers' own evidence suggests that there may be problems at the formal level. For example, farmers all agreed that the extension officers working in their villages met principally with those farmers who were members of specialist crop clubs. The membership of these clubs is predominantly male. It appears that a distinction is being made here between principle and practice. In principle, there is no reason why a keen female farmer should not be as capable as anyone else of requesting information. However, in practice it may well be harder for a woman to approach the FA, a professional and 'outsider' male. In practice, women give more time than men to subsistence crops and to marketing, so they have less time to grow cash crops. Similarly, women have a range of domestic duties to perform so have less time to sit and listen to the radio; fewer women than men are literate, so fewer can read extension literature. These findings suggest that there are structural differences between men and women in their access to formal networks of communication in agriculture. Such differences suggest that at the informal level, if more information is transmitted primarily from men to men and women to women, women would have less access to information gained through formal networks. This issue cannot be addressed here due to lack of data.

CONCLUSIONS

So what do these findings mean for the FSIPM Project in disseminating its work to a wider farmer audience? Firstly, and familiarly, we have found that the formal extension services are overstretched, under-resourced and demotivated. However, the good news is not only that radio is the medium of choice for the farmers interviewed, but also that approximately 50% of households in Malawi own radios (Dr Katherine Chibwana, personal communication, 1999). Listening rates are also said to be high. This suggests that radio is probably the best way of disseminating useful material. Written materials are said by farmers to work well, but from the extension point of view are expensive and limited in their ability to reach women farmers.

It also appears that farmer-to-farmer extension not organized by an outside agency may be problematic due to fears of jealousy. Farmers need some form of legitimation to spread information beyond their immediate family and friends.

There may be possibilities implicit in the success of the specialist crop groups. Extension workers prefer to work through specialist groups – might the formation of 'termite' and 'whitegrub' groups by farmers provide a model for self selection?

The methodology of on-farm trials also appears to have been successful as a demonstration plot, unlike extension demonstration plots. Farmers' preference to learn from their own and others' practice close to home appears clear. The success of our farmer field days also offers a useful model for farmer learning. There has been considerable enthusiasm from farmers for seeing how things are done elsewhere, and the opportunities this gives for fresh insights.

However, the personnel and cost implications of the FSIPM model (three seasons in farmers' own fields with 16–30 replications per village) must be taken into account when considering these findings. It is likely that the original extension model would have worked with adequate funding.

Finally, and reassuringly, it is probable that if technologies or practices developed by the project are appropriate for the needs of resource-poor farmers information about them will pass from farmer to farmer, but slowly, and along kin and neighbour lines, as seen with the spread of cultivar ICP 9145, or ridge technology. Helping farmers to learn more quickly, however, must remain at the top of our agenda.

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DISCUSSION

D. Coyne. Do innovators exist in Malawi villages, and what do you think about targeting these households for demonstration, especially considering they are already (usually) better off?

J. L.-M. Innovators do exist – although they are not easy to identify, for example, by key informant routes, because fellow villagers avoid public naming of co-villagers for fear of getting them into trouble or being accused of doing so. We did not deliberately target those households for demonstration because (i) we were running trials not demonstrations, (ii) we were targeting resource-poor farmers, (iii) there are social prohibitions against looking at others' fields except in the context of external organization/self-organization of farmer groups. This we had only achieved by the third year (also the time when demonstration plots might have been appropriate, e.g. green manure technologies) and the project is ending.

V. Kabambe. Did you check if the farmers listened to the agricultural programmes or simply noted those with radios? Also, would it not help to find out what other programmes they enjoyed, for example, plays, as this type could also be used. If farmers liked to listen to political rallies then messages could be included in these programmes.

J. L.-M. Yes, farmers themselves cited radio as a source of learning about agricultural innovations. We did not ask about what type of programme best spread a message (cf. 'The Archers' in the UK) but it would be a good topic for future research.

V. Saka. Did you find out how many radios were available in the village where you worked?

J. L.-M. Not the whole village, but we asked farmers in the discussion groups and 61% had radios. Most of these radios had been running for the last few weeks (we asked if a lack of batteries meant radios had not been used).

R. B. Jones. Did you find that information flowed to farmers from rural retailers (stockists)?

J. L.-M. Farmers in the groups did not mention retailers of any description. This surprised us since we had hypothesized that stockists would be a good source of information. We did not prompt farmers since we were looking for spontaneous comments. However, I agree that it is very unlikely that retailers are not a source of information and cannot explain why farmers did not mention them.

F. M. T. Gondwe. Extension staff were not assigned to some of the project sites, e.g. Mombezi. Did the FSIPM Project at any point attempt to get help from the relevant authorities so that farmers might have access to extension workers in such areas?

J. L.-M. No, we did not. I suppose that this did not seem to be an appropriate action. When extension officers were not in place, arrangements tended to be made by ADD HQ to have other extension officers act as caretakers. However, these officers already felt overworked and under-rewarded so were not keen to do extra work without financial incentives.

Integrated Crop Management Research in Malawi: Developing Technologies with Farmers.
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Disseminating research results to researchers, extensionists and farmers: what have we got and how should we package it?

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ABSTRACT

This paper briefly reviews the technologies which have been developed or tested by the Farming Systems Integrated Pest Management (FSIPM) Project on the basis of on-farm trials which have provided baseline information, technical performance data and farmer evaluation assessment during this process. It is proposed that the experience gained by the project within Blantyre/Shire Highlands can best be made available to researchers wishing to continue participatory on-farm research by developing a range of materials which document the major characteristics of the farming system and describe the evolution of the research methods used within the project, as well as setting out the main technical findings of the project in relation to the specific crops and crop/pest management technologies studied. The needs of extensionists may best be met by developing short illustrated texts which describe the use of specific technologies and their expected outcomes under a range of conditions. The key feature of such aids must be to set out a flexible menu of options from which farmers can make informed choices based on an appropriate understanding of the external factors influencing crop success, in addition to the nature and severity of the problem being directly addressed by the technology. For farmers themselves, simple vernacular leaflets or other messages are suggested which will illustrate how to carry out specific practices, emphasizing once again the need to make choices from a menu of options rather than adopting a single invariable 'researcher recommendation'.

INTRODUCTION

The Project Memorandum of the Farming Systems Integrated Pest Management (FSIPM) Project (BDDCA, 1995) originally set out the documentary outputs expected from the project. As the project progressed it became clear that an unusual combination of methodologies was being utilized to investigate the farming system and to evaluate technologies with farmers. Successive Department for International Development (DFID) reviews developed a further output which was to document this process. The relevant sections of the logframe dealing with these outputs are given in Table 1. This has been modified in the light of more extended descriptions by DFID reviews of their requirements (Hansell *et al.*, 1998).

AVAILABLE TECHNOLOGIES FOR EXTENSION

The technologies researched on-farm by the FSIPM Project are shown in Table 2 with a brief assessment of possible extension outputs. The aims, methods and results of each of these technologies have been clearly documented at this Workshop.

Management of *Striga*

In the case of the management strategies for *Striga* there are already some indications of trap crop effectiveness in reducing *Striga*, and green manures clearly make the maize more competitive and improve yield (Chanika *et al.*, p. 216 and p. 256). However, given the increased level of outputs now expected from the project by DFID (Table 1, Output 5) and the original obligation to produce three extension messages (Table 1, Output 3) it is essential to set priorities for the extension outputs. It is, therefore, deemed appropriate that pest management strategies for *Striga* should not be selected for extension in their present form.

Bean varieties for pest management and yield

The least clear outcome is that of bean varieties where the project has shown that in general under farmer management, improved varieties released from the Bean Improvement Programme with superior pest and disease resistance perform less well than a short duration farmers' variety (Kaulesi). In addition, short season varieties are able to command a premium in the market as well as helping to meet the need for domestic food security during the 'hungry period'. Though this is an important finding, it is not clear what message can be disseminated more widely beyond passing back findings to the Legume Commodity Team. This has been done and they have already started multiplying seed of short season bean varieties (Kaulesi and Nyadanawo) for evaluation (R. M. Chirwa, personal communication). There is clearly a need for market-led participatory research and development with farmers to increase availability of suitable short duration varieties.

Table 1. Extracts from Project Memorandum as modified by DFID to show the nature of expected documentary outputs from the FSIPM Project

Narrative summary outputs	Measurable indicators	Means of verification
2.2 IPM strategies suitable for resource-poor farmers developed	2.1 At least one pest management strategy per crop by end year 2	2.1 Project reports
3.3 Improved extension materials prepared and disseminated by both formal and informal extension networks	3.1 Three packages of extension materials (one per crop for verified pest management strategy) developed by end year 3	3.1 Project reports and extension materials
5.5 Full documentation and archiving of all project trials data, analysis, recommendations and methodologies used	5.1 Archive of trial and survey data	5.1 Archive to be updated annually
	5.2 Recommendations for farmers and extension workers	5.2 Preliminary materials to be tested during 1998/99 field season
	5.3 Record of project methodologies and evolution of project philosophy	5.3 Existing documentation to be supplemented by specific reports during write-up period at end of project
	5.4 Descriptions of local farming system characteristics	
	5.5 Lessons for DFID	5.4 and 5.5 as for 5.3

Source: Ritchie *et al.* (1999).

Table 2. Possible output dissemination pathways for technologies developed or tested by FSIPM Project

Crop	Problem	Technology	Workshop paper (this volume)	Action needs
Maize	*Striga*	Green manures/ trap cropping (plus weeding)	Chanika *et al.*, p. 216 and p. 256.	Develop proposals for continuing on-farm validation of green manures and trap cropping for *Striga*
Maize	Termites	Weeding without banking	Ritchie *et al.*, p. 77.	Prepare leaflet for extension staff on farmers' weeding strategies
Maize	Whitegrubs	Gaucho seed dressing	Ritchie *et al.*, p. 60.	Submit justification plus draft extension leaflet to Technology Clearing Committee
Beans	Improved yield under farmer management	Shorter duration varieties	Ritchie *et al.*, p. 164.	Brief Department of Agricultural Research and Technical Services (DARTS) Legume Commodity Team on farmer priorities and on-farm performance of improved varieties of beans in Blantyre/ Shire Highlands. Develop proposal for participatory variety development?
Pigeonpea	Improved yield and quality; wilt suppression	ICEAP 00040 (*Fusarium*-resistant, high yielding)	Ritchie *et al.*, p. 180.	Submit justification plus draft extension leaflet to variety release committee. Agree responsibilities between ICRISAT/FSIPM/MoAI?
Sweet potato	*Cylas* weevils	Crack sealing	Mwale *et al.*, p. 48.	Prepare descriptive leaflet for extension / farmers

Table 3. Projected documentary outputs from the FSIPM Project

Description of expected output	Length	No of copies	Logframe Output number	Intended audience
Compilation of major internal project reports, 1996–2000	600 pp	50	Outputs 2 and 5	DARTS and other researchers
Proceedings of Final Project Workshop	400 pp	200	Output 2	Workshop participants, other farming systems projects, NGOs, DARTS, donors
Archive of trial and survey data	CD-ROM	20	Outputs 2, 3 and 5.1	DARTS and other researchers
Extension leaflets in English (for extensionists) and in Chichewa (for farmers) for cultural management of: • termites • sweet potato weevil	12 pp	For each: 5000 in Chichewa; 400 in English	Output 3	Extensionists, NGOs, farmers
Submissions for Technology Clearing/ Variety Release Committee and extension leaflets in English (for extensionists) and in Chichewa (for farmers) on: 5 use of Gaucho as a seed dressing for whitegrub management 6 performance of ICEAP 00040 pigeonpea	10 pp	10	Output 3	MoAI policy-makers, researchers, extensionists, NGOs
Summary overview of pest management trials for: • maize (termites, whitegrubs, *Striga*) • pigeonpea (*Fusarium* wilt) • beans and sweet potato (*Cylas* weevil)	20 pp	200	Outputs 2, 3 and 5	Researchers, senior extension personnel, NGOs, projects, donors
Description of farming system and evolution of project's philosophy, approach and methods for on-farm IPM research	100 pp	200	Output 5	Researchers, senior extension personnel, NGOs, projects, donors
Lessons from the FSIPM Project (for DFID)	20 pp	200	Output 5	Researchers, senior extension personnel, NGOs, projects, donors

POTENTIAL OUTPUTS FROM THE FSIPM PROJECTS

A list of projected documentary outputs from the FSIPM Project is shown in Table 3.

Methods handbook

An externally facilitated internal FSIPM Project planning meeting in May 1999 (Sutherland, 1999), produced a draft list of possible methods used by the FSIPM Project which could be described in a methodologies publication (Box 1). It is suggested that each method will be covered by a short paper of 2–3 pages which will include the purpose for the method, one or two clear examples of using the method, tips, pros and cons relating to the method and resources required (skills, time, equipment and materials).

Description of the farming system, outline of trials, evolution of project philosophy and lessons for DFID

This could make use of the sustainable livelihoods framework in order to describe the livelihood system of the project area, including the farming system – this would make it more relevant to output 5 and future DFID programme design for southern Malawi (Sutherland, 1999).

This output should include a summary overview of the pest management trials and describe the evolution of the project's philosophy. It will also present the overall lessons of the project for future donor-funded initiatives with smallholders in Blantyre/Shire Highlands.

Box 1. Some methods for participatory on-farm research used by the FSIPM Project

Starting: developing initial understandings, contacts and focus

Reconnaissance surveys (key informant interviews)
Stakeholder analysis and meeting (lessons)
PRA/RRA tools to describe farming systems including:
- transect survey walks (*Striga*, etc.)
- walk around fields
- social mapping (for farmer selection)
- resource mapping (sweet potatoes?)
- timelines (pest outbreaks)
- crop calendars and enterprise diagrams (sweet potatoes)
- semi-structured interviews (pest strategies)

Methods of identifying problems and selecting options?

Getting into deeper understanding and analysis of socio-economic processes

Baseline survey (lessons)
Farm mapping/plan (for diagnosis and modelling)
Indigenous knowledge (tillage and weeds)
Decision trees (management of weeding)
Field measurement (modelling and trial analysis)
Panel surveys (continuity for focused one-off investigations)
Personal histories (support long-term case studies)
Case studies – both short and longer term (household and social relations)
Activity diaries (labour)
Cluster analysis (for targeting and grouping of farmers)
Computer modelling

Experimentation on farmers' fields

Trial designs (researcher and farmer designs and issues of whose agenda)
Bio-physical data requirements
Statistical analysis (unbalanced data, sampling specialist groups)
Open-ended evaluations (criteria for questionnaires)
Scoring farmer preferences (statistical analysis, etc.)
Ranking criteria for farmer evaluation
Preparing questionnaires (lessons)
Group vs individual farmer evaluation

Taking up opportunities, developing trust, networks and responsive planning

Informal discussions
Developing personal contacts (to build trust and continuity)
Networking (with other researchers and organizations, e.g. Action Aid) and handing on
Meetings and group discussions (for planning and monitoring and evaluation)

Endings

Final evaluation meetings
Farmer to farmer lessons and farewell
Planning endings: handing over strategies and approaches

Source: Sutherland (1999).

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DISCUSSION

A. A. Chirembo. Would it not be important to also present future research areas and possibly even the design of the study, particularly for areas where no conclusive results are available, for example, termite study in maize where the results are not clear?

J. M. R. At this stage of the FSIPM Project we need to use our remaining time to disseminate information on IPM strategies for extensionists/farmers as our first priority, However, we would welcome interest in pursuing research issues where we can offer advice.

N. Nsanjama. I thought that Dr Chirembo's comment was to propose that there should be a statement on the way forward for technologies that have not been fully refined.

J. M. R. Some technologies (e.g. banking/not banking) may not justify further research but for those that do, hopefully the discussion group on research may list and prioritize them.

R. B. Jones. The list of dissemination media outlined are fairly conventional. Can we think of more active/proactive methods?

J. M. R. I would welcome any initiatives which are financially viable and can be carried out within the lifetime of the project.

K. M. Chavula. I note from Table 2, you have indicated that some technologies will be referred to the Technology Clearing Committee while others you will package straight away in the form of leaflets. Why have you made this distinction?

J. M. R. In the case of Gaucho as an insecticide and ICEAP 00040 as a new pigeonpea variety, there is a requirement for official clearance for release of a new technology. In the case of the other technologies, these are already in use in some form in Malawi.

4. Increasing Yields from Smallholder-managed Legumes

KEYNOTE ADDRESS

Improving poor farmers' access to technologies and markets for pigeonpea in Malawi

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ABSTRACT

Liberalization of input and product markets in Malawi has presented smallholder farmers with a range of challenges and opportunities. To take advantage of these developments, smallholder farmers must be able to participate in productive activities in which they have a competitive advantage. This implies access to well-organized marketing, distribution and post-harvest systems, effective market information, and technologies that allow them to be competitive in both price and quality. Pigeonpeas are widely grown in southern Malawi, both for food and as a cash crop. Despite the ready availability of international markets, there has been little attempt to understand and respond to end-user requirements. These need to be given priority so that private sector traders and processors can target high-value niche markets that offer a significant price premium over traditional markets. To respond to higher quality requirements in niche markets, exporters have to develop better market arrangements to stimulate investment by farmers in improved seed and realize the productivity and quality gains that have been demonstrated from planting improved varieties. This paper describes a strategic partnership between public and private organizations and NGOs to re-establish Malawi as a reliable producer of high quality pigeonpea.

INTRODUCTION

During the post-independence period, Malawi prided itself on being self-sufficient in food. Emphasis was placed on maize production using hybrid seed and fertilizer with input and output prices being carefully regulated to maintain a constant ratio between input costs and output prices. Seasonal loans for inputs were provided to farmer clubs through the Smallholder Agricultural Credit Administration (SACA), and the whole enterprise was supported by a comprehensive network of extension agents, backed-up by a small but competent research service. Although smallholder farmers grew cash crops such as groundnuts, cotton, and certain types of tobacco, the most profitable crops were reserved for commercial estates. The mix of crops grown by smallholders during this time very much reflected the input and output price interventions of government so, for example, when the relative price of groundnuts compared with maize changed in favour of maize, groundnut production collapsed and hybrid maize became an important cash crop. Despite the achievement of national food security in most years, the system was not equitable. In 1993, Malawi was found to have some of the highest levels of malnutrition and under-five infant mortality in the world (Government of Malawi, 1993).

Malawi has undergone significant political and economic reform during the closing decade of the 20th century. In the agricultural sector, the monopoly of the parastatal marketing board ADMARC, ended in 1987. From 1990, the burley tobacco sector started to open up with the allocation of a burley quota to smallholder farmers. In 1993, the SACA, which provided seasonal loans to farmers for the purchase of inputs, predominantly hybrid maize seed and fertilizer, collapsed. In 1995, the removal of subsidies on agricultural inputs and the devaluation of the Malawi Kwacha, led to a 300% increase in the price of fertilizer.

Declining household and national food security has triggered a range of policy interventions. The liberalization of the burley tobacco sector has increased rural incomes and had a positive effect on household food security for the top quartile of rural farmers (Peters, 1999). The greatest financial benefits from burley are derived by farmers in well-organized burley groups, who are receiving credit, are supported by extension workers and who deal directly with the auction floors. Where land is poor and farmers do not have the necessary support structures, benefits are minimal (Evans, 1997). The challenge facing Malawi is how to improve food security and incomes for the majority of farmers who do not grow burley tobacco and are unlikely to do so because they lack the necessary skills and resources (land, labour and cash). In 1998, the Starter Pack Programme was started to improve both household and national food security (Longley

Table 1. Average production (t) and area (ha) of pigeonpea in Kenya, Malawi, Tanzania and Uganda for 1980–82 and 1995–97 and annual growth rate in production for 1980–97

Country	Production (t) Av. 1980–82	Production (t) Av. 1995–97	Area (ha) Av. 1980–82	Area (ha) Av. 1995–97	Annual growth rate in production (1980–97)
Kenya	28 845	44 874	66 337	147 510	4.7
Malawi	85 000	98 000	127 333	143 000	0.8
Tanzania	22 667	37 333	36 667	56 667	2.2
Uganda	26 333	58 333	55 000	71 000	6.1

Source: Freeman *et al.* (1998).

et al., 1999). The original idea behind the starter packs was to provide smallholder farmers with improved maize seed and fertilizer with which they can learn, on their own fields, how to use the new area-specific fertilizer recommendations, and diversify their cropping system through the adoption of grain legume rotations (Mann, 1998).

The increased attention of policy-makers and researchers on legume production to diversify the maize-dominated cropping system is an important component of any strategy to improve soil fertility. The logic is clear; legumes fix their own nitrogen and perform well in low-nitrogen soils, they complement the maize-based diet because of their high protein content, and there are good local, regional and international markets.

There are important lessons to be learnt from the liberalization of the burley sector, and the increased understanding of how the poorest households survive in a liberalized market economy. Apart from the provision of credit, successful burley farmers have benefited from good extension advice and improved market arrangements. Although burley tobacco is grown purely as a cash crop, the lessons learnt can be applied to legumes which are grown both for food and sale. Despite the existence of high-value niche markets for legume crops, there are no producer incentives to invest in technologies that already exist to improve productivity. Input markets for legume seed are virtually non-existent, transaction costs in marketing are high, and information on markets and their requirements is poor. There is an incorrect assumption that food-deficit households only grow crops for food. Mwale *et al.* (1999) working in Blantyre/Shire Highlands, found that the market was an important component of household livelihood security.

This paper argues that a balance has to be struck between investments that increase production and those that improve market arrangements reducing transaction costs and increasing the returns to legume production. Without the necessary incentives, farmers are unlikely to invest in improved seed and realize the productivity and quality gains that have been demonstrated from planting improved varieties. Examples are drawn from Malawi to show how such a process can be started.

OVERVIEW OF PIGEONPEA PRODUCTION IN EASTERN AND SOUTHERN AFRICA

Pigeonpea is one of the major grain legume (pulse) crops of the tropics and sub-tropics, ranking sixth in area and production after other grain legumes such as beans, peas and chickpeas (Nene and Sheila, 1990). India is the world's leading producer as well as its major consumer of the crop, where it is an important human food. The dry seed is dehulled, and the split cotyledons, referred to as *tur, toor, tuver* or *arhar dhal*, are cooked to make a thick soup, primarily for mixing with rice. Pigeonpea is also grown in eastern and southern Africa (Table 1) for household consumption, and for export primarily as unprocessed peas, but also in the processed form. Malawi, is the biggest exporter of *tur dhal* in Africa, and also exports significant amounts of whole pigeonpeas.

Pigeonpea is unique in that it combines pulse production with drought tolerance, low-labour demands, production of fuelwood, and soil fertility amelioration. Pigeonpea enhances the available supply of phosphorus by solubilizing iron-bound phosphorus. The crop biologically ploughs the soil with a deep rooting system; protects the soil from erosion, fixes substantial amounts of nitrogen in low-fertility, dry environments, and produces high quality residues that recycle nitrogen and phosphorus to subsequent crops.

Like other legumes, pigeonpea is susceptible to insect pests. Of these, weevils are of primary importance, predominantly *Callosobruchus chinensis*, which can penetrate the pigeonpea pods and infest the grain in the field before harvest. Poor storage facilities and limited technical knowledge on fumigation practices requires the crop to move quickly through the rural marketing chain to ensure that middlemen are not left with weevil-infested grain. The larger traders, who export the whole grain, have better storage facilities and the technical expertise to fumigate the stored product.

Although pigeonpeas are well adapted to the farming systems where they are grown, their sensitivity to both daylength and temperature results in restricted production within those systems. Once the phenology of the crop was understood (see Silim *et al.*, 1994), it became possible to develop earlier maturing varieties. The ability to produce pigeonpeas

Table 2. Main income crops for households relying on crop sales as primary income

Size of household cropped area (ha)	Maize	Cassava	Sweet potato	Tobacco	Groundnut	Pigeonpea
<0.5	23.5	20	30.6	15.3	22.4	20
0.5–1.0	30	13.8	18.4	23.5	34.6	6.9
1.0–1.5	35.1	9.7	15.3	41.5	41.5	5.2
> 1.5	44.1	6.5	10.8	56.3	45.2	2.5

Source: Longley *et al.* (1999).

throughout the year, from a wide range of improved varieties with different maturity periods, has opened up new market opportunities, including the export of fresh peas to the UK and dry grain to India, during periods when supplies from alternative sources are low and hence, market prices are highest. Plant breeding research has also incorporated other important favoured market characteristics, such as preferred grain size and colour, in addition to high yields in improved pigeonpea varieties.

In Malawi, pigeonpeas are grown by smallholder farmers in the southern region of the country. The dominant planting system is to intercrop long duration varieties with maize at the start of the rainy season. Harvest of dry pigeonpeas starts in August, although green pigeonpeas, primarily for home consumption, are harvested from July onwards. The labour requirement associated with the cultivation of long duration pigeonpeas fits well with the availability of household labour. The main labour input is for harvesting that takes place well after all other crops are harvested and when there are limited opportunities to undertake *ganyu* labour. The fact that pigeonpeas can be intercropped means that they maximize the returns to land, which is the one of the major resource constraints facing poor smallholder farmers. The importance of the crop to farmers with limited landholdings is shown in Table 2. Crops that require more labour, such as tobacco and groundnuts, are more important for households cultivating larger areas.

A market-driven approach to agriculture shifts the focus from production issues, to learning about the market and understanding end-user requirements.

Table 3. Analysis of an FAQ pigeonpea shipment from Myanmar to India

Analysis	Percentage
Foreign matter	1
Weeviled	2.5
Damaged	3.0
Foreign beans	0.2
Broken	0.2
Total	6.9

Source: Jaeger (1998).

INDIA'S MARKET

India is the world's largest producer, importer and consumer of all types of dried and processed pigeonpea products. Domestic consumption of pigeonpea reached 2 million t in 1996/97, the latest figures available. In 1999, Africa exported more than 60 000 t to India (Jaeger, 1998). These exports came largely from smallholder farmers growing traditional long duration varieties that are harvested in August-September and then exported as fair average quality (FAQ). The quality standards for FAQ are based on the amount of weevil damage, manifested as holes in the grain, and the percentage of trash in the grain sample. Clearly, market standards are very low – a recent shipment from Myanmar accepted in India as FAQ was analysed as shown in Table 3.

There is great scope for expansion of these export sales. In 1995/96, India imported 82 000 t, while in 1996 this rose to 132 000 tons (Figure 1). Estimates for the 1998/99 season are as high as 200 000 t, due to bad growing conditions in the production areas. India's pigeonpea deficit is projected to continue to grow (Jaeger, 1998). Almost all imported grain is whole grain for *dhal* production. India makes a great effort to protect its *dhal* industry and imposes severe import duties on imported *dhal*. However, recent policy changes now favour the consolidation of the processing industry into larger plants in urban centres. As these plants develop, the demand for the raw product is expected to shift, favouring higher quality and more timely year-round supply, than is available domestically.

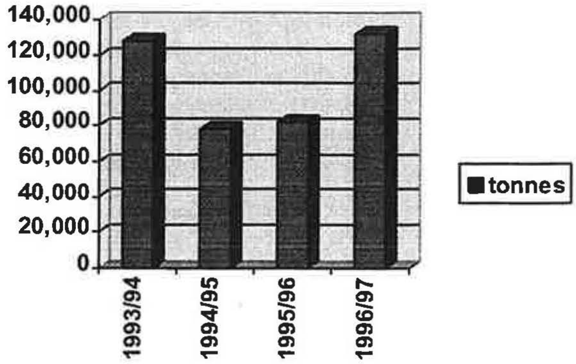

Figure 1. Indian imports of unprocessed pigeonpea. Source: Indian Foreign Trade Statistics.

EUROPEAN MARKETS

The principal importer and consumer in Europe is the UK, owing to its large population of peoples of Indian and Caribbean descent. Imports of other European nations are negligible, other than those by Portugal to supply the Cape Verde Islands.

Recent market research in Europe indicated a significant niche market for high quality grain (Jaeger, 1998). Pigeonpeas grown in northern Tanzania are sought by European buyers because of their favoured bold cream-coloured grain. However, the quality standards for the European market dictate that the percentage insect damage has to be less than 1% with a far lower level of trash tolerance than for the Indian FAQ market.

The principal supplier of dried pigeonpeas and *tur dhal* to the UK is Malawi and this origin is taken as the benchmark grade. The UK imports approximately 1500 t from Malawi annually. Other markets for split pigeonpeas include North America, mainly for the large Asian immigrant population in the USA and Canada.

Export of the processed product *tur dhal* is of course attractive, as it permits capture of additional value by local agro-processors. The percentage recovery of *dhal* from whole grain is dependent upon several factors including the ease with which the seed coat can be removed from the cotyledons, the size and the shape of the grain.

ALTERNATIVE PRODUCTS/MARKETS

There also appear to be potential markets for a range of alternative pigeonpea products, including fresh, organic, frozen and canned.

Demographic change is creating a demand for immigrants' traditional foods in their new homes, and changing work patterns mean there is a greater demand for convenience foods. The large Indian and Afro-Caribbean communities found in Europe and North America offer new potential markets, while improved processing technologies have led to the development of convenience foods based on *dhal*. In all cases, these markets offer a significant premium over the traditional Indian market.

The demand for organic foods in the USA, Europe and elsewhere is growing rapidly as a result of health and other concerns (Thompson, 1998), and offers another potential market opportunity. Pigeonpea is an attractive primary and rotational crop for organic production because of the soil fertility benefits that it brings, essential where inorganic fertilizers are not permitted.

Though the potential market for frozen and canned pigeonpeas has not yet been fully assessed and presently no such processing is being done in Africa, the current work is being undertaken in hopes of continued innovation and market development.

In order to take advantage of identified high-value niche markets that pay a significant premium over the undiscriminating Indian market for FAQ whole grain, a system of clear and easily administered quality standards must be developed and accepted. Without such standards, quality premiums will not reach the farmer and there will be little incentive to invest in improved pigeonpea technologies.

THE PIGEONPEA INDUSTRY IN MALAWI

The first *dhal* mill was started in 1958 by Universal Agencies. Since that time, a further 10 *dhal* mills have been commissioned giving Malawi an installed capacity to process approximately 20 000 Mt of *tur dhal* per annum. Apart from exporting *tur dhal*, most companies also export unprocessed pigeonpeas. Before export and processing can start, the crop has to be assembled and transported to the *dhal* mills situated in and around Limbe and Blantyre. This activity is carried out by a network of rural assemblers and transporters who do not specialize in pigeonpeas alone, but purchase a wide range of crops from smallholder farmers. It is estimated that approximately 30% of the crop delivered to the dhal mills actually originates from Mozambique. Timing is critical as unprocessed pigeonpeas destined for the Indian market have to be delivered by mid-November as prices start to decline with the harvest of the Indian crop. With the re-opening of the Nacala Corridor, pigeonpeas are transported by rail to Nacala for onward shipping to their final destination. A full size container has a capacity of 21.5 t and costs US$ 1900 CIF Mumbai. After mid-November, exports of whole pigeonpeas to India wind down in favour of *tur dhal* and some unprocessed pigeonpeas to markets other than India.

The other major pigeonpea producing countries in the region have a similar crop cycle. The main difference is that all countries, with the exception of Uganda, have lower freight charges than Malawi. Only Kenya has the capacity to produce *tur dhal* but its industry is much less developed than Malawi. For all countries, the primary export market for unprocessed pigeonpeas is India. In some years there is a significant cross-border trade in whole peas from Tanzania to Kenya where there is a sizeable domestic market for the crop. The demand from Kenya can lead to a significant increase in price for Tanzanian producers after the expiry of the mid-November deadline, but when Kenya has a good crop, prices collapse after traders stop buying for the Indian market as there is little domestic demand within Tanzania. Whole pigeonpeas from Babati District in northern Tanzania have a well-established reputation in the demanding European Market where they are referred to as 'Arusha White'. The local varieties grown have bold cream-coloured seeds and these are exported as a sideline by established commodity traders operating out of Arusha who are involved in the growing and marketing of seeds, predominantly beans.

In the mid 1970s, Mozambique was a major exporter of whole pigeonpeas. During the civil war, exports were disrupted but farmers living in the border areas continued to grow the crop and sell to traders from Malawi. With the cessation of hostilities in 1993, Mozambique has identified pigeonpeas as a potential export crop and significant investments are being made by the private sector, NGOs and the government to re-establish the pre-eminent position Mozambique enjoyed before the war. Malawi, because of its high transport costs relative to Mozambique and other producers in East Africa, is unlikely to have a comparative advantage in the export of FAQ pigeonpeas to the Indian market. The Malawi industry does have an established reputation in world markets for *tur dhal*, and processors have a well-developed network of market contacts. However, in this era of globalization and free trade, the advantage gained from market information is unlikely to be sufficient for the industry to compete in the medium to long term. It is essential that the industry strives to identify new marketing opportunities and establish a competitive edge over other producers.

Several trends have started to emerge that have important implications for Malawi. First, the ability to produce pigeonpeas that meet the more demanding quality standards associated with non-traditional export markets attract a significant price premium over FAQ exports to India. Second, the ability to produce *tur dhal* not only adds value but allows for diversification of export markets. Third, strong domestic demand can be a significant marketing opportunity for both whole and processed peas. Finally, there are emerging opportunities for alternative products and markets that have yet to be exploited. For the Malawi industry to be pro-active rather than responsive to changes that are taking place, it is essential that effective partnerships are developed between the full range of institutions that have an interest in the pigeonpea sub-sector. These include research and extension organizations, NGOs, the private sector and farmers themselves.

In 1999, the first step towards establishing an effective partnership was completed with the registration of the Dhal Millers Association Limited (DMAL)[1]. A major objective of the association is to increase collaboration between the various players involved in the pigeonpea sector including the government, agricultural research and extension organizations and NGOs. The DMAL is not a purchasing and marketing cartel. Individual members compete to purchase the crop from traders and for export markets. Three areas have been identified where they need support:

- increased pigeonpea production within Malawi to compensate for the predicted decline in sales from Mozambique as traders in that country start to compete for the crop;
- to improve the quality of the Malawian crop so that Malawi can establish a competitive edge over its competitors;
- to access good market information so that the industry can exploit new opportunities.

If these issues are not addressed, not only will those employed by the industry suffer, but so will the thousands of smallholder farmers who earn some cash income from the sale of the crop.

INCREASING PIGEONPEA PRODUCTION AND QUALITY

One of the major constraints to producing high quality pigeonpea for overseas markets is the lack of improved seed. It is in reality, however, just the 'egg' side of a classic, 'which comes first, chicken or egg?', dilemma. Private investment in new seeds, production methods and post-harvest systems is unlikely in advance of the market being prepared to pay for these products and services. Introducing the market to new products and standards, however, is difficult without adequate levels of production.

This problem is made worse by out-of-date national policies on mandated new varietal testing and approval processes. It is further complicated by a general lack of regional co-ordination and policy harmonization, creating international barriers to the dispersal of, and trade in, improved seed.

Clearly, to be truly sustainable, the supply of improved seed has to be based on profitable commercial terms. This poses a serious problem for a relatively minor crop like pigeonpea, for in addition to the problems already cited, the commercial seed sector is in general moving away from multiplying and distributing seeds of open pollinated crops.

Wiggins and Cromwell (1995) have examined the reasons why the commercial seed sector is reluctant to invest in crops not produced as hybrids. First, transaction costs in seed markets can be unusually high for both buyers and sellers. Farmers encounter the costs of acquiring reliable information about new varieties and they face the risk of buying inappropriate or poor quality seed. From the supplier perspective, it is expensive to discover farmers' preferences and their outlays are increased by the inventory, storage and wastage costs incurred in having to provide multiple varieties of seed in small amounts at the right time, and carrying stocks sufficient to meet uncertain and fluctuating demand. There are, of course, the additional issues of intellectual property rights and farmer-saved seeds.

Two strategies have been employed to expand the supply of improved pigeonpea seed to smallholder farmers. One strategy is to market small seed packs to farmers through a combination of public, commercial and local-level participation. NGOs and various local-level organizations are experimenting with options that attempt to improve seed supply, but these efforts are limited in scope.

In both Kenya and Malawi, pilot seed marketing exercises were carried out to determine whether there was an effective demand for seed of several non-hybrid crops. Small seed packs of non-hybrid crops were successfully marketed to farmers in both Kenya and Malawi through extension agents, health centres and local traders. Although there was an effective demand, the profit margins were not adequate to be of interest to the commercial seed sector.

[1]At a meeting of the Dhal Millers Association Limited held on 17 November 1999, the Association agreed to change its name to the Grain and Legume Development Association Limited and to expand its interests to include both groundnuts and chickpeas as well as pigeonpeas.

The alternative strategy is to hand over responsibility for seed production to the processors and exporters of the crop – those who have a direct interest in the quality of the final product.

COLLABORATION WITH THE PRIVATE SECTOR IN MALAWI TO IMPROVE SEED SUPPLY

In Malawi, where there is a well-developed network of pigeonpea exporters and processors, the recently established DMAL was concerned about the declining quality of the crop that they were purchasing from farmers, a significant amount of which originates across the border in Mozambique (Ackello-Ogutu and Echessah, 1998; Whiteside, 1998). The DMAL recognized that they needed to address both crop productivity and crop quality if the industry was to remain viable.

ICRISAT and the Department of Agricultural Research and Technical Services (DARTS) were testing a number of improved pigeonpea varieties with farmers. Grain samples were given to the DMAL for evaluation together with the results of laboratory analysis on dehulling percentage. The association identified an improved wilt-resistant long duration variety, ICEAP 00040, which had also performed well in on-farm trials in Malawi and elsewhere in the region.

Attention shifted to how to get this seed into the hands of farmers – who would invest in seed multiplication and promote distribution and adoption? In this case there was a clear incentive for the DMAL to participate, as its members would benefit from the increased supply of higher quality grain.

ICRISAT and DARTS supplied the foundation seed to DMAL for this exercise. DMAL underwrote the cost of contracting farmers to multiply this seed in the 1998/99 season to produce 100 t of seed, sufficient to plant 20 000 ha in the 1999/2000 season.

The introduction of price incentives for grain produced by farmers planting improved seed, streamlining seed multiplication efforts to reduce costs, and the involvement of local-level initiatives can potentially increase margins sufficiently so that such initiatives at least break even. Under this scenario, there are strong reasons for the private sector to be at least partially involved in input supply so that they realize gains from other activities that are dependent upon the supply of improved seed.

FARMER ORGANIZATION

The comment that farmers only receive a fraction of the price paid to traders and processors is often made whenever there is interaction between government, NGOs and the private sector. Before making such assertions, it is necessary to understand the marketing chain and the cost structures associated with it. It is only through such an understanding that interventions can be designed to reduce transaction costs. First, it is not easy to deal with large numbers of smallholder farmers that are geographically dispersed. The experience with smallholder burley production is a good example of the benefits that accrue to farmers if they can be organized into effective groups. Farmers need to be educated on how markets work, and what actions they need to undertake to benefit from those markets. The flow of information between end-users, processors and farmers is an essential component to the efficient functioning of markets. In Malawi this information flow is virtually non-existent.

Information flow alone will not achieve desired results. Systems have to be put in place that can react to the information in a way that will achieve the desired result. Most importantly, such systems have to be streamlined so that changes can be implemented quickly in response to new opportunities. Global markets and changing tastes are particularly fickle as any tobacco farmer in Malawi will testify.

The establishment of farmers' marketing organizations offers farmers a number of potential benefits. It might allow farmers to engage in more stable (less risky) relationships with suppliers or traders: by offering a substantial amount of grain to preferred buyers, farmers may be able to attract larger, inter-regional traders, who are willing to offer a better price than local middle-men and to provide farmers with better market information (Risopoulos *et al.*, 1999). In Malawi, resource-poor smallholder farmers have not benefited from the development of farmers' marketing organizations that have largely focused on burley tobacco. There is a role for NGOs, who target resource-poor smallholders, to assist such farmers to benefit from improved marketing arrangements.

CONCLUSIONS

This paper has argued that a market-driven approach to agriculture is fully consistent with increased livelihood security for poor smallholder farmers. To ensure the success of such an approach, a balance has to be struck between investments that increase production, and those that improve returns to legume production.

There is a urgent need for better collaboration between research and extension organizations, NGOs, the private sector and farmers themselves. Malawi does not have a strong comparative advantage in the production of any commodity due to the high transport charges incurred as a result of its landlocked position. It is essential that attention be given to improved marketing and agro-processing to add value to commodities that are well adapted to the agro-ecological and socio-economic conditions found in the country. Systems need to be developed that will provide incentives to farmers to adopt improved technologies, and new partnerships are required to ensure that farmers are fully informed about market requirements.

The pigeonpea sub-sector is a success story for Malawi, but unless greater effort is made to assist the Malawi pigeonpea industry, competition from other countries in the region will erode the advantage that the country presently enjoys.

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DISCUSSION

D. Makina. You indicated that one of the threats to the pigeonpea industry in Malawi is declining quality which is due to the varieties grown. You said that ICEAP 00040 was identified as a better variety by the pigeonpea processing companies. Was ICEAP 00040 the only variety that these companies recommended? If yes, should Malawi concentrate on fulfilling the wishes of this market alone? There has been a sharp decrease in pigeonpea prices this year probably due to over-production and if we concentrate on a single market we might have problems.

R. J. No, ICEAP 00040 was not the only variety. The Grain Legume Development Association is also interested in short and medium duration varieties. Pigeonpea prices always tend to decline in mid-November as the Indian crop is harvested. Indeed the point of my paper was to stress the idea of looking at alternative markets, but these require higher quality standards.

B. Mwale. The role of markets in improving accessibility to improved technologies is indeed critical. With respect to the pigeonpea market in Malawi, the industry needs to play a role by giving farmers incentives for growing improved varieties. Currently there is no price premium for growing improved varieties.

C. Kaunda. Is it practical for Malawi to develop co-operatives through which farmers can sell their pigeonpeas or any other crops?

R. J. Yes, but unfortunately the history of co-operatives in Africa has not been good due to political interference. However, they can be very effective if managed properly.

F. Simtowe. I am particularly impressed by the rigorous market research done on pigeonpea by your team and the steps you have taken to form a grain legume advisory board. Do you think you should now establish a market intelligence team so that they keep society informed of changes in market demand for pigeonpea?

R. J. Yes, we are working closely with Technoserve, an NGO specializing in enterprise development, to develop a regional market intelligence system. In the long term, we see this as being provided on a commercial basis and may even be extended to link buyers to producers through an internet platform.

R. J. Chapweteka. You have mentioned the quality of seed being a contributing factor to the low quality of pigeonpea in Malawi. Do you think that this problem is not communicated to the people who supply pigeonpea seed?

R. J. One of the main problems is poor communication between the private sector and research and extension. What I am suggesting is that the needs of the end-user should be considered in variety development and selection.

V. Saka. Have we learnt any lessons from past exports of fresh produce to Europe?

R. J. Before doing this, it is important to understand the cost structure of the marketing chain and whether Malawi has a comparative advantage over other countries.

V. Kabambe. You show that pigeonpea is common on farms of less than 1 ha where it is grown as an intercrop. Do you think that pigeonpea can be cultivated as a sole crop?

R. J. I believe that the ability to grow pigeonpea as an intercrop is a major incentive for smallholders with less than 0.5 ha. As insect pests are a major problem of short and, to a lesser extent, medium duration varieties these should only be targeted to farmers who have the ability to spray, e.g. cotton farmers. Perhaps the industry can assist in this together with NGOs and extension departments.

Bean seed supply strategies in Malawi

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ABSTRACT

Farmers have shown considerable interest in purchasing seeds of newly released bean (*Phaseolus vulgaris* L.) varieties in Malawi. However, this seed is not available on a large scale to farmers at present. The private seed sector in the country is not interested in bean seed production due to low profit margins. As a self-pollinating crop, once farmers have obtained initial seed stock, it can be recycled for some time. A strategy has been developed to focus on alternative sustainable informal seed production and dissemination systems which builds on lessons learnt from previous experiences within Malawi and other African countries. These include: (i) informal seed multiplication, using smallholder farmers; (ii) informal seed distribution channels, using grocery shops, rural traders, extension agents, health clinics and NGOs; and (iii) intensified variety promotion through publicity, using posters, leaflets, brochures and radio messages. These activities are carried out in close collaboration with farmers, NGOs, extension agencies, village traders and various other institutions.

INTRODUCTION

Beans are an important food crop as a source of protein for many Malawians and also a source of income. The crop is mostly grown by smallholder subsistence farmers, most of whom are women. It is grown throughout Malawi, but commonly in areas between 1000 m and 1700 m above sea level during the rainy season, with mean annual rainfall of 800–1500 mm. Farmers grow bean under several cropping systems: pure stand, mixed stand with other crops, usually maize, relay crop after maize, in *dimba* gardens on residual moisture, under irrigation after rice in rice schemes, and in alleys of tree crops.

Total bean production in Malawi is low. The national average bean production was only 27 500 t in 1989 and rose to 60 500 t in 1998. The total land area grown to beans has expanded from 93 500 ha in 1989 to 170 000 ha in 1998. However, the yield per unit land area has changed slightly: from 294 kg/ha in 1989 to an estimated 356 kg/ha in 1998 (Table 1). Bean yields obtained under farmer conditions are far below those realized under well-managed research station conditions which are in excess of 1500 kg/ha. There are many factors that significantly constrain bean production under smallholder farm conditions in Malawi. These include biotic, abiotic and socio-economic factors. The main biotic constraints are diseases (angular leaf spot, common bacterial blight, halo blight, anthracnose and common bean mosaic virus) and insect pests (bean stem maggot, aphids, *Ootheca* beetle and bruchids) (Wortmann *et al.*, 1998). The major abiotic constraints include low soil fertility and water stress, whereas the most important socio-economic constraints are lack of seeds of improved varieties, poor pricing policies, lack of affordable farm inputs and poor storage facilities.

TECHNOLOGY DEVELOPMENT FOR BEAN PRODUCTION

Since beans are important in the diet of Malawians, there have been considerable research efforts to develop improved bean production technologies.

Bunda College of Agriculture released six bean varieties in 1980. Out of these, four are dwarf types, i.e. Nasaka, Sapelekedwa, Bwenzilawana and Kamtsilo, and two, i.e. Namajengo and Kanzama, are the climbing type. Breeders' seed of these varieties was provided to the National Seed Company of Malawi for further multiplication and distribution, but the company's interest in seed of self-pollinated crops had declined at that time because farmers were able to recycle the seed from their previous crop for a few years before renewing their seed stocks. As a result of this, many

Table 1. Bean production statistics for Malawi, 1989–98

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Production (t)	27500	27600	38700	30000	45300	25100	30900	49600	53100	60500
Area (ha)	93500	96500	116300	127000	132900	106300	112200	128200	172200	170100
Yield (kg/ha)	294	286	333	239	360	237	275	386	307	356

Source: FEWS (1993).

Table 2. Breeder's seed multiplication by contract farmers in winter 1999

Variety	Site	Contracted farmers	Seed (kg)	Projected production (kg)
Mkalira	Kamuona	1	25	500
Maluwa	Kamuona	1	25	500
Sapatsika	Kamuona	1	25	500
Nagaga	Kamuona	1	25	500
Kambidzi	Kamuona	1	25	500
Napilira	Zidyana	1	25	400
Total		217	140	2900

farmers did not have access to these improved bean varieties (Mkandawire, 1992). Bunda released three other varieties in 1993. These are Bunda 93 (a local accession), Chimbamba (derived from a cross between two local accessions), and Kalima (an introduced line).

In 1995, the Department for International Development (DFID)-funded Bean Improvement Programme (BIP) at Chitedze Agricultural Research Station, released six new bean varieties: Napilira, Maluwa, Nagaga, Sapatsika, Mkhalira, and Kambidzi (Chirwa *et al.*, 1996). They represent two gene pools: (i) the first four are of the Andean type and are large seeded, (ii) the last two are of Mesoamerican origin and are small seeded. All originated from International Centre for tropical Agriculture (CIAT) in Colombia.

STRATEGIES FOR SEED MULTIPLICATION IN THE BEAN IMPROVEMENT PROGRAMME

The BIP has developed strategies and mechanisms that can support and accelerate the transfer of technologies to farmers in a sustainable manner. Some of the strategies are already in use.

Primary (breeder and basic) seed production

The BIP has a target of producing breeder and basic seeds of improved varieties each year. This seed is currently multiplied through one or more of the following channels.

Research station farms

Breeders' seeds are produced at the research station farms or by contracted farmers under direct supervision of the breeders to ensure the purity of the varieties (Table 2). The involvement of research scientists also helps to maintain a strategic reserve of the pure seed. The subsequent seed is then injected into further seed multiplication systems.

Contracted large-scale and smallholder farmers

Further basic seed is multiplied through collaborators, both large- and small-scale farmers (Table 3). These farmers have a direct contract with the BIP. The contract clearly details that the BIP will buy back the seed from farmers at grain market price plus 10% premium. The system has successfully operated since 1996 and all contracted seed growers have sold their seed to BIP. The quantities of seed realized over four seasons are as follows: 18 t (1996), 40 t (1997), 25 t (1998) and 50 t (1999).

Secondary (commercial or non-commercial) seed multiplication

Although the system for producing primary seed is working well through the project, the quantities of seed produced are far too small to meet the bean seed requirements for the nation. There is a need to put into place a sustainable mechanism to supply large quantities of seed. The ultimate success of the seed system will depend on secondary seed multipliers who work closely with farmers or have easy access to farmers. Already such mechanisms exist both at the government (Action Group II of the Maize Productivity Task Force) and the non-government level (various NGOs), and their involvement in seed multiplication will be important for a steady and sustainable seed supply system. The BIP has already initiated bean seed multiplication activities with them as discussed below.

Collaboration with government organizations

Action Group II of the Maize Productivity Task Force is within the Ministry of Agriculture and Livestock Development and focuses on small-scale farmers in the rural communities who

Table 3. Basic seed multiplication by contract farmers, winter 1999

Variety	Site	Farmers	Seed issued (kg)	Projected total production (kg)	Projected production (kg)
Maluwa	Kamuona	86	2145	21450	21450
Napilira	Zidyana	6	120		1200
	Kamuona	6	133	2530	1330
Sapatsika	Zidyana	7	140	1400	1400
Nagaga	Zidyana	16	400		4000
	Kamuona	65	1625	20250	16250
Kambidzi	Zidyana	11	165	1650	1650
Mkhalira	Zidyana	20	300	3000	3000
Total		217	5028	50280	50280

Table 4. List of farmers from Blantyre/Shire Highlands RDP requesting to multiply bean seed in 1999

Farmer	Variety preference		
	1st	2nd	3rd
Mbulumbuzi Section			
Mwayi Wathu Women's Group,			
Maulana Village			
1. Mai Nethar Naison	Kalima	Nagaga	Mkhalira
2. Rose Sailes	Kalima	Nagaga	Mkhalira
3. Sophia Mphepo	Kalima	Nagaga	Mkhalira
4. Margaret Mphepo	Kalima	Nagaga	Mkhalira
5. Mary Nthungo	Kalima	Nagaga	Mkhalira
6. Rose Likhwiya	Kalima	Nagaga	Mkhalira
7. Catherine Medison	Kalima	Nagaga	Mkhalira
8. Dorothy Mili	Kalima	Nagaga	Mkhalira
9. Margaret Zuze	Kalima	Nagaga	Mkhalira
10. Mercy Mwamadi	Kalima	Nagaga	Mkhalira
Lirangwe Section			
Chiwinja Village			
1. Malita Sapuwa	Mkhalira	PAD3	G22501
2. Mai Mlonda	Mkhalira	Nagaga	
3. Mai Maduka	Nanyati	PAD3	G22501
4. Mai Magreen	Chimbamba	PAD3	Napilira
5. Mai Chintedza	Mkhalira	Chimbamba	Napilira
6. Mai Chilewe	Chimbamba	Kaulesi	
7. Mai Stella Sapuwa	Mkhalira	PAD3	G22501
8. Mai Enala Limala	Mkhalira	PAD3	G22501
9. Mai Kaminyu	Nanyati	PAD3	G22501
10. Mai Walala	Chimbamba	Napilira	Nagaga
Lidala Village			
1. Mai Kusala	Chimbamba	Nanyati	PAD3
2. Bambo Charles Sapanga	Nagaga	Chimbamba	Kaulesi
3. Bambo Kasimu Sapanga	Nanyati	Nagaga	PAD3
4. Bambo Dyson Chimwanza	Chimbamba	Nanyati	Kayera
5. Mai Dorothy Ayimu	Kambidzi	G22501	Chimbamba
6. Mai Tangale	Nanyati	Chimbamba	Kambidzi
7. Mai Chipakula	Nagaga	Kambidzi	Mkhalira
8. Mai L. Mpenda	Kalima	Napilira	Kaulesi
9. Mai Bitoni	Napilira	Chimbamba	Kaulesi
10. Mai Mdala	Nanyati	Kanzama	Chimbamba
11. Mai Teleza Luwera	Chimbamba	Mkhalira	Kalima
12. Mai Saina Kadango	Chimbamba	Nanyati	Kayera
13. Mai Ester Thom	PAD3	Chimbamba	Nagaga
14. Bambo Kaunda Nelson	Kalima	PAD3	G22501
15. Mai E. Mpenda	Mkhalira	PAD3	G22501
16. Mai E. Mwadala	Kaulesi	Nagaga	Kalima
17. Mai E. Nankhonya	Mkhalira	PAD3	Kaulesi

Source: FSIPM Project, Bvumbwe Research Station.

are interested in seed production and marketing as a business. These communities have now formed associations. Some of these farmers are interested in beans. The BIP strategy is to work closely with Action Group II of the Maize Productivity Task Force to identify farmers who are willing to take up secondary bean seed multiplication as a business in the major bean growing areas. The BIP provides backstopping through supply of breeders' seed, basic seed and technical support. During the 1998/99 crop season, the BIP supplied over 10 t of basic seed to Action Group II for both large-scale contracted farmers and small-scale farmers in seed association groups.

The BIP has experienced demand from farmers who want to become involved in bean seed multiplication after being exposed to bean production technologies through other government activities. A good example is the exposure farmers had to new bean varieties through on-farm research organized by the Farming Systems Integrated Pest Management (FSIPM) Project in the Department of Agricultural Research and Technical Services at Bvumbwe Research Station. The project worked with farmers in Blantyre/Shire Highlands Rural Development Project (RDP) in Malawi. Although spreading the new bean varieties was not the main aim of the study, those farmers who were exposed to new varieties

Table 5. List of farmers from Mombezi EPA issued with bean seed for the multiplication programme

Farmer	Bean variety	Amount of seed issued (kg)	Expected repayment (kg)
Mbulumbuzi Section			
Mwayi Wathu Women's Group			
1. Mai Bethar Naison	Nagaga	10	15
2. Mai Rose Sailesi	Nagaga	10	15
3. Mai Sophia Balala	Nagaga	10	15
4. Mai Margaret Mphepo	Nagaga	10	15
5. Mai Mary Nthungo	Nagaga	10	15
6. Mai Rose Likhwiya	Nagaga	10	15
7. Mai Catherine Medison	Nagaga	10	15
8. Mai Dorothy Mili	Nagaga	10	15
9. Mai Margaret Zuze	Nagaga	10	15
10. Mai Mercy Mwamadi	Nagaga	10	15
Lirangwe Section			
Chiwinja Village			
1. Mai Malita Sapuwa	Mkhalira	10	15
2. Mai Malonda	Nagaga	10	15
3. Mai Maduka	Mkhalira	10	15
4. Mai Magreen	Nagaga	10	15
5. Mai Chintedza	Mkhalira	10	15
6. Mai Chilewe	Napilira	10	15
7. Mai Stella Sapuwa	Napilira	10	15
8. Mai Enala Limula	Nagaga	10	15
9. Mai Kaminyu	Nagaga	10	15
10. Mai Walala	Nagaga	10	15
Lidala Village			
1. Mai Kusala	Mkhalira	10	15
2. Bambo C. Sapanga	Nagaga	10	15
3. Bambo K. Sapanga	Nagaga	10	15
4. Bambo D. Chimwaza	Mkhalira	10	15
5. Mai D. Ayimu	Kambidzi	10	15
6. Mai Tangale	Kambidzi	10	15
7. Mai Chipakula	Mkhalira	10	15
8. Mai L. Mpenda	Kambidzi	10	15
9. Mai E. Mpenda (Harrison)	Mkhalira	10	15
10. Mai Bitoni	Mkhalira	10	15
11. Mai Mdala	Napilira	10	15
12. Mai T. Luwera	*Withdrew, did not like Mkhalira*		
13. Mai Saina Kadango	Mkhalira	10	15
14. Mai Ester Thom	Napilira	10	15
15. Bambo K. Kaunda	Mkhalira	10	15
16. Mai Mwadala	Mkhalira	10	15
17. Mai Nankhonya	Mkhalira	10	15

Source: FSIPM Project, Bvumbwe Research Station.
Total input distribution of 10 kg each: Nagaga 17; Napilira 4; Kambidzi 3; and Mkhalira 13.
Total=37 farmers.

have now started to multiply the seeds for sale to others in their communities. Requests for seed of specified varieties by farmers were made through the Ministry of Agriculture and Irrigation and the FSIPM Project (Table 4). The BIP has supplied basic seed of the varieties that are under its control (Table 5).

It was interesting that the farmers' lists of requested varieties included some that are still experimental varieties (G22501 and PAD 3) and one farmers' own local variety, Kaulesi. The FSIPM Project has found that in Blantyre/Shire Highlands RDP, Kaulesi is one of the most preferred bean varieties by farmers for various attributes, especially early maturity (Orr *et al.*, 1999). It is generally scarce on the market and when available, the price is usually very high compared to other varieties. However, one would find it difficult to understand why fewer farmers opted to multiply seed of Kaulesi when there is so much market demand for it. This calls for a better understanding of the social, economic or biological factors that influence farmers' selection of varieties. Such factors as desire to add new stocks of varieties to their existing lots, or new varieties that would sell better or faster would influence selection of varieties. It could also be that new varieties performed better than local ones in terms of yield.

Collaboration with non-governmental organizations

Various NGOs such as Action Aid, Christian Services Committee, Concern Universal, Self-help Development International, Veza International and Primary Health Care participate in the seed production and distribution sector in Malawi. The BIP's strategy is to work jointly with NGOs by supplying them with seed of improved bean varieties that they can distribute to their farmers for multiplication. During the 1998/99 crop season more than 17 t were supplied to NGOs.

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DISCUSSION

B. Mwale. Low private participation in both production and trade of beans may be the result of weak information flows as well as low profit margins. Neither farmers nor traders can make informed choices if they do not have information. Currently, the seed sector is characterized by a lack of nation-wide publicity to highlight the seed sector liberalization policies and the availability of high yielding varieties that meet farmers requirements. The majority of smallholder farmers have still not yet been exposed to some of the bean varieties that were released a long time ago.

Those farmers and traders with the right information (production to marketing) are making a reasonable profit out of bean production. In Blantyre/Shire Highlands, our experience is that farmers in the area are specializing in the production of beans, not only as a food crop, but also as a cash crop. Prices are freely determined depending on the demand and supply situation. High prices are realized in times of shortage and low prices are obtained in times of plenty, with quick maturing varieties getting the highest premium price.

Why did FSIPM Project farmers opt for other bean varieties (particularly Kambidzi and Mkhalira) rather than Kaulesi when Kaulesi has always been said to be a highly demanded bean variety? A number of observations come to mind.

For Blantyre/Shire Highlands, it remains an undisputed fact that Kaulesi (both in Chiradzulu and Thyolo) is highly favoured by farmers (see Ritchie *et al.*, p. 164). It always has a high price premium. Even in times of plenty, the price of Kaulesi is almost double the average price of any other bean variety in Blantyre/Shire Highlands local markets. During planting time and even in February, you can buy Kaulesi at Bvumbwe Market at no less than MK100/kg, when the other bean varieties are sold at almost two-fifths of that price. Farmers like Kaulesi variety particularly for its early maturity. Some farmers nickname it *Mchotsa njala*.

Again, the farmers we are talking about here are those who have been receiving Kaulesi during the period of the project. Informal surveys of input supply that the project was carrying out prior to the planting season showed that most of these farmers kept seeds of those crop varieties that they liked, both bean and pigeonpea. The *Mwayi Wathu* group of Maulana village actually produced 16 kg of usable Kaulesi seed, a good portion of which they kept for the next planting.

Some of the improved varieties, especially Kambidzi and Mkhalira, which farmers planted for the first time, fortunately, performed very well under intercropping on farmer observation *Kanthu Nkako* plots. It is, therefore, understandable for farmers to want those varieties for seed multiplication. In addition, it should be noted that these farmers knew that this was the last season of the project and, therefore, this would be their last chance to get supplies of improved bean varieties.

An informal FSIPM Project survey on *'How farmers avoid bean pests and diseases without even trying'* (Orr et al., 1999b), revealed that farmers prefer to eat fresh beans for as long a period as possible. To ensure a supply of green beans over a long period, therefore, farmers select varieties with different maturity dates. Some late maturing varieties, like *Kayera wang'ono,* are prized not just for their supply of late fresh beans, but also for their tender leaves which farmers said are tastier than those of other bean varieties.

We also found in another informal survey (Orr *et al.*, 1999a) on *'Games farmers play: control strategies for whitegrubs'* that farmers were reluctant to name others from whom they had learnt of seed dressing with Sevin against whitegrub attack; several claimed to have invented it. This is normal rational behaviour. We all want to be the first to have brought an innovation into an area. So in this case, some of the farmers may just have wanted to be among the first few farmers who multiplied improved bean varieties which had never been in the area before.

In summary, it takes a lot of time and patience to know the dynamics of farmers' own decision-making when it comes to variety selection. This is very important for the success of any programme.

Implications for the Bean Improvement Programme

There is an opportunity for promoting bean varieties with a wide range of characteristics that will be acceptable to the farmers. Farmers want both quick-maturing bean varieties and late-maturing varieties for their own reasons. There is potential to promote improved bean varieties that are medium-maturing but high yielding (Kambidzi and Mkhalira) along with other short duration varieties that may not be as high yielding as other improved varieties. In Chiradzulu, farmers nicknamed Mkhalira and Kambidzi *Kaunjika*, implying very high yielding.

A nationwide variety demonstration programme could strengthen adoption of these improved bean varieties. Farmers should be empowered to own the demonstration process. This will help to increase demand for improved bean seed.

Sustainable Bean Improvement Programme

What mechanisms are put in place to ensure sustainability of the programme where the government is involved in buying back the seed from farmers using donor funding? We have heard before of the marketing problems that this type of arrangement faced with the EU-funded smallholder bean seed multiplication programme. What lessons have been learnt from that programme? We need to build in elements of how this type of programme will continue to operate once the donor leaves.

In a liberalized seed sector environment, government's role should be more of a facilitator than a key player. It should help in creating a conducive climate for more participation of private traders in bean production and marketing to support its policy of liberalization. Both farmers and traders need information on the economics of bean production and trade.

With respect to the involvement of NGOs in the seed sector, there should be close liaison and clear objectives, because some existing NGO programmes are not sustainable due to their emphasis on relief operations.

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On-farm trials of bean varieties for yield and pest resistance

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ABSTRACT

This paper reports the results of three seasons of researcher-designed on-farm trials (1996/97 to 1998/99) of pest management strategies against pests attacking smallholder beans in Blantyre/Shire Highlands, under farmer management intercropped with maize and pigeonpea in the case of the summer crop, and relayed with the maize/pigeonpea intercrop for the winter bean crop. In 1996/97 the candidate pest management strategies were targeted mainly at bean stem maggot (BSM) which has been recognized by researchers and indirectly by farmers (under the guise of wilting or *kunyala*) as a major problem in beans. These were varietal tolerance, mulching, earthing-up, high density planting and seed dressing with Sevin (carbaryl), already used by some farmers as a maize seed dressing. Other treatments were applied simultaneously in a factorial design to the maize and the pigeonpea, including a treatment for termite damage in maize in which mature maize plants are isolated from the surrounding soil by forming a new ridge in the furrow, on which a relay crop of beans is planted (*kaselera*). The new *kaselera* ridges caused the relay beans to desiccate, reducing yields by an average of 28.7 kg (P=0.05), so this practice was replaced in the second season by a related technique (*mbwera*) in which the removed soil is spread within the furrow to create a flat planting area for the relay bean crop. In 1996/97 seed dressing with Sevin generally inhibited germination leading to reduced plant stand and yields, except in the relay crop, where heavy BSM damage probably destroyed most plants in the control plots while treated plots retained more plants. In 1997/98 and 1998/99, all treatments apart from varieties were abandoned in response to poor performance and adverse farmer evaluation. Napilira, Kalima and Nagaga were added to Kaulesi, and Chimbamba was dropped. In summer-intercropped beans, diseases exerted a significant negative effect on bean yields, especially in Matapwata. Deaths due to BSM rose to a peak about 6 weeks after planting before falling back and then rising rapidly to a much higher level around 12 weeks after planting. The performance of Kaulesi was generally as good as or better than research varieties when intercropped under farmer management. Gaucho (imidacloprid) seed dressing applied to the maize intercrop significantly increased maize yields, but was found to depress intercropped bean yields significantly. Declining bean yields due to winter drought led farmers to discontinue experimentation on winter beans after the second season. A survey of 40 farmers participating in the trial in May–June 1998 indicated that excessive rain, pod rot, wilting and burning of leaves were perceived as the main problems on beans in 1997/98 season. The most commonly mentioned pest was *Ootheca* (35% of responses), while pod borers were cited in 25% of responses. Farmer criteria for bean variety evaluation were elicited and used to score acceptability of varieties. Using weighted indices derived from farmer criteria, Kaulesi was found to be significantly preferred to Chimbamba, while Chimbamba was significantly preferred to Napilira, Nagaga and Kalima.

INTRODUCTION

Background

The Farming Systems Integrated Pest Management (FSIPM) Project, financed by the UK Department for International Development (DFID) and the Government of Malawi, and based within the Department of Agricultural Research and Technical Services at Bvumbwe Research Station, has been conducting on-farm trials and investigations to develop appropriate pest management recommendations for major pests of maize, bean, pigeonpea and sweet potato which can be extended to resource-poor farmers in the Blantyre/ Shire Highlands Rural Development Programme (RDP) area of Blantyre Agricultural Development Division. The initial crop focus of the project was determined by a Stakeholder Workshop in June 1996 which also highlighted particular key pests (Ritchie, 1996). The rationale for selection of specific EPAs within the RDP and specific villages within those EPAs has been documented by Ritchie *et al.* (1997).

Purpose of the study

Infestation of beans (*Phaseolus vulgaris*) by larvae of beanflies (*Ophiomyia* spp.), known generally as bean stem maggot (BSM), is common and frequently severe in southern Malawi, especially in the rainy season when beans are intercropped with maize. Infected plants often die soon after germination or are greatly weakened as a result of stem damage by beanfly larvae and the associated invasion by fungal infections, especially *Fusarium* wilts (Letourneau, 1991; Ampofo, 1993) and *Sclerotium* root rot. This synergistic association makes BSM possibly the most serious pest of common beans.

It appears that farmers are generally unaware of BSM as the cause of dead bean plants in their plots, and view the wilting and death of plants as a form of blight (Letourneau, 1991). However, diagnostic surveys and pest risk assessment exercises with farmers during 1996 revealed wilting as the highest-ranked constraint to bean production in Blantyre/Shire Highlands. Wilting in beans is caused by (*Ophiomyia* spp., although farmers in southern Malawi were not aware of the activities of this particular pest at the commencement of the FSIPM Project (Riches *et al.*, 1993). In relation to intercropped beans, the purpose of the trials conducted over 3 years of FSIPM activities was, therefore, to develop appropriate pest management strategies for BSM while at the same time assessing the relative effects of other pests and diseases on bean yield under farmer management. The specific aim of these trials was to increase smallholder bean yields.

This report summarizes the main findings of experimental trials conducted on-station and on-farm, with the aim of evaluating a range of pest management strategies for the control of BSM.

STUDY DESIGN FOR TRIALS IN THE 1996/97 SEASON

Selection of study areas and farmers

Following discussions with extension staff in Blantyre/Shire Highlands and a reconnaissance survey, two EPAs, Chiradzulu north and Matapwata, were chosen as the location of on-farm trials. From each EPA, two villages were selected. Farmers' fields were generally either *dambo* or upland fields. This difference in land type was expected to influence the incidence of pest populations. For the main intercrop trial involving maize, bean and pigeonpea, 16 farmers were selected from each land type (hereafter referred to as zones) and from each EPA, giving a total of 64 farmers in the first year of experimentation (1996/97). There was a reasonable representation of farmers from each of the four villages selected. The distribution of farmers among villages, EPAs and zones is shown in Table 1.

Social mapping exercises were carried out in each of the villages in order to make the appropriate selection of farmers. The selection was also influenced by farmers' attendance at farmers' meetings concerning the FSIPM Project.

Farmers agreed to two plots being used for testing IPM strategies. One plot was designated the 'research' plot and included an IPM strategy for each intercrop. The second plot was designated as the 'farmer's' plot. The farmer was asked to cultivate this plot according to his/her current practice.

Context and objectives

The 1996/97 main intercrop trial was conducted with 64 farmers in four villages in two EPAs. This trial was set within the maize/pigeonpea/bean intercropping system with relay cropping of bean or field pea, which is the commonest cropping system in Blantyre/Shire Highlands. The objectives and design of the experiment have been detailed by Ritchie *et al.* (1997).

Selection of treatments

The range of available pest management strategies for BSM at the inception of the FSIPM Project was as follows.

Foliar insecticide sprays

In practice this approach seemed unlikely to be appropriate for resource-poor farmers as they have no access to suitable chemical formulations or application equipment. The safety implications are also of concern.

Seed dressings

Endosulfan has been successfully used as a seed dressing in several countries in Africa (including the Soil Pests Project at Chancellor College), but is now classified as moderately hazardous (WHO, 1990) and is not regarded as acceptable. Yields have increased by 17–21% with endosulfan alone, and in combination with fungicides such as thiram and benomyl yield increases ranged from 14% to 63%. A safer insecticide with some persistence and some systemic action in the germinating beans is needed. One economic analysis of the combined insecticide/fungicide seed treatment in Rwanda quoted a cost per ha of US$4–6 with a benefit–cost ratio of 5.0–22.2 for bush and climbing beans, respectively (Trutmann *et al.*, 1992). Isofenphos (Oftanol) has been recommended by one study (Kabungo

Table 1. Distribution of farmers in the 1996/97 season across villages and land types

Land type (zone)	Chiradzulu		Matapwata		
	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	8*	8*	10	6	32
Upland	8	8	6	10	32
Total	16	16	16	16	64

*Chiradzulu *dambo* farmers were not included in the bean trial as they do not grow beans on *dambo* fields.

et al., 1994). In the FSIPM trials, Sevin (carbaryl) wettable powder was selected for assessment in 1996/97 because it is widely available in Malawi and is relatively cheap (MK23.5 for 100 g in 1996). It is known to have slight systemic action and soil treatments can reduce both nematode and aphid attack. It was expected to produce a more marked reduction of beanfly damage than non-insecticidal approaches.

Varietal resistance

Bean resistance to BSM is believed to be largely based on the ability to tolerate damage. It is not clear whether varieties with proven resistance are available for distribution to farmers. The variety Kalima was extensively tested by Bunda College for its agronomic qualities and acceptability to farmers before release in 1993, and is known to be tolerant of beanfly attack. An older variety, Kaulesi, is widely grown in East Africa (also known as *kablanketi* and *mwezi moja*), and was reported by Kapeya (1995) to be the most tolerant of the local varieties assessed in his studies of beanfly. Kaulesi was compared with the most widely grown local variety, Chimbamba, in the FSIPM intercrop trial (1996/97) in Matapwata and Chiradzulu and in a follow-up relay crop trial in Matapwata only. Kalima was observed for possible future use by incorporating it as an intercrop into the 1996/97 *Striga* trial.

Mulching

Use of various plant residues (dry banana leaves, rice straw, dry bracken) as mulch has been investigated and found to reduce and stabilize soil temperature while conserving moisture. This causes enhanced growth of adventitious (but not lateral) roots which aids survival after BSM stem damage (Ampofo & Massomo, 1996).

Early planting

Where practicable, early planting is known to reduce BSM attack at the vulnerable seedling stage (Abate, 1990; Davies, 1990), although occasionally later planting may miss the peak of the pest population.

Earthing up

In Tanzania, earthing up plants to encourage adventitious roots has been claimed to be effective in reducing mortality due to BSM infestation (Kabungo, 1994). Yield improvements are not great.

Increased plant population

This may reduce infestation levels and increase yields at densities up to 300 000 plants/ha (Abate, 1990).

Natural enemies

Despite high rates of parasitism (up to 93%) by a wide range of parasitic wasps, parasitoids do not appear to regulate pest populations and kill the BSM when it has already inflicted damage (Abate, 1990; Davies, 1990). Management strategies should seek to avoid disrupting existing control by natural enemies. The use of a short-lived seed treatment rather than foliar spraying of chemicals may be expected to cause less damage to natural enemy populations.

Botanical pesticides

Data presented by Ampofo (1993), showing improved yield and apparent reduction in feeding and pupation of BSM on plants treated with neem and *Tephrosia* extracts, offer some interest. An on-station trial to assess the effectiveness of these methods was carried out in association with the Bean Improvement Programme at Chitedze and Bvumbwe in 1996/97 but did not show any useful effects (Bean Improvement Programme, 1997; Abeyasekera, 1998).

Multiple interventions

There is agreement between different studies that the integration of several different approaches is likely to give the greatest reduction in losses caused by BSM and associated infections (Abate, 1990; Ampofo and Massomo, 1994; Kabungo, 1994). In the 1996/97 FSIPM on-farm trials, seed dressing, varietal tolerance, earthing up, mulching and increased plant density were combined.

Pest management strategies

A range of possible pest management strategies were discussed with farmers for inclusion in on-farm trials during the 1996/97 season. Farmers were not aware that wilting was caused by beanfly and were willing to try seed dressing with Sevin as a control method. Other interventions suggested to farmers were mulching, earthing up, and increasing the planting density. Farmers thought that mulching might encourage attack by termites. Grass for mulching was also scarce. Farmers also felt that earthing up might encourage termites, but were willing to try this method. Increased planting density posed problems because of shortage of seed, but again farmers were willing to try this provided they were given seeds for the trial. Kaulesi and Chimbamba were chosen for testing of varietal tolerance to BSM.

Thus five pest management strategies were selected for inclusion in the 1996/97 trials. These included innovative farmer practices; interventions which had been tested by researchers; and interventions developed by researchers which had not yet been tested. In statistical terminology these are referred to as five factors, each being tested at two levels, i.e. with or without the intervention. The five factors chosen were:

- variety: Chimbamba or Kaulesi
- mulching: yes/no
- earthing up: yes/no
- planting density: high (three bean stations between adjoining maize and pigeonpea stations) or low (one bean station between adjoining maize and pigeonpea stations)
- seed dressing with Sevin: yes/no

An additional factor was included for testing in the relay crop of beans: the use of *kaselera* ridges formed from previous maize ridges compared with the *mbwera* system of planting on the flat.

Allocation of treatment factors to research plots on farmers' fields

The treatment factors to be tested with respect to the bean crop were a subset of a range of pest management strategies that were carried out for the overall intercrop farming system. Other strategies related to the control of whitegrub and termite attack on maize plants and on the control of *Fusarium* wilt in pigeonpeas. The full range of treatment factors used in the main intercrop trial is summarized by Abeyasekera *et al.*, p. 28, together with the planned layout.

The experiment was designed to ensure that final responses measured with respect to bean harvests could be analysed to study the effect of the five bean treatment factors, and possible two-way interactions between these factors, for control of BSM. The design was, therefore, a fractional factorial replicate of a 2^5 factorial experiment in three blocks, each having 16 plots, i.e. 48 experimental plots in total, one per farmer. The three blocks comprised Matapwata *dambo* fields, Matapwata upland fields and Chiradzulu upland fields. Chiradzulu *dambo* was not included in the bean trial as the diagnostic surveys indicated that farmers in Chiradzulu did not grow beans in *dambo* fields. The design layout given by Abeyasekera *et al.*, p. 28, for Chiradzulu *dambo* does not include any of the bean treatment factors.

The advantages of combining trials of pest management strategies for the different crops within one on-farm experiment are listed by Ritchie *et al.* (1997). These include the fact that the approach mirrors the actual farming system; interactions between different pest management strategies and resource competition can be detected and obviated; logistics are simplified by dealing with a limited area and farmer group; a factorial design cuts replication and reduces plot numbers and associated labour and expense.

The actual treatment levels used during the course of the trial were slightly different from the planned design because some farmers did not carry out the suggested treatment combinations. The greatest change occurred with earthing and mulching, where most farmers did neither earthing nor mulching. The actual treatment structure that farmers eventually used is given by Abeyasekera *et al.*, p. 28.

MATERIALS AND METHODS

Plot layout

Each farmer provided land for two adjacent plots, each measuring 10.8 by 10.8 m. Plots were ridged at 90 cm intervals and were bounded by a box ridge. One plot per farm was used as the experimental plot and the other was left as a farmer's plot with maize and intercropped pigeonpea and other crops provided by the farmer. Maize (MH 18 in 1996/97 and Masika in 1997/98) was planted at 90 cm intervals with 3 seeds/station. Pigeonpea (either local variety, locally purchased, or ICP 9145) was planted midway between maize plants, at 90 cm intervals.

Plot management

The experiment was researcher-designed and farmer-managed. Planting (and fertilizer application in 1997/98) was carried out by the research team assisted by farmers. Weeding and banking were carried out by farmers. In 1996/97 no fertilizer was applied in order to model the realistic situation on many farms where fertilizer was unaffordable. In 1997/98 fertilizer (23:21:0 + 4S) was applied at emergence by dolloping both sides of the planting station to achieve 50 kg N/ha. Recording of stand counts and pest damage was carried out roughly every 2 weeks by the research team. Harvesting was carried out by researchers, assisted by farmers where available. All yield was returned to farmers.

Measurements recorded during data collection activities

Measurements made at harvest time included the number of plants with pods, the total pod weight and the total seed weight. During the season, damage data were collected at each of four sampling occasions. These were the number of plants killed by stem/root rot, beanfly, *Alcidodes*, mechanical damage, other insects and other diseases. Also recorded was the number of plants damaged by non-fatal causes.

Methodology for statistical analysis

Statistical procedures used in analysing data from the FSIPM on-farm trials involved fitting a general linear model when the response data were on an interval scale of measurement (e.g. yield data), or a generalized linear model when the data were in the form of counts, e.g. the number of *Alcidodes* in a random sample of 10 plants, or in the form of proportions, e.g. the proportion of plants attacked by BSM during the season. The first of these types of model assumes that the model residuals, the components left over after accounting for all known sources of variation, are independent of each other and follow a normal distribution with a zero mean and a constant variance (Mead, 1988). Modelling data in the form of counts typically gives residuals that follow a Poisson distribution, while data in the form of proportions have residuals that follow the pattern of a binomial distribution. Models which allow data from non-normal distributions to be analysed, via appropriate transforms of the response, while at the same time recognizing the true distributional form of the data, fall into the class of generalized linear models (Dobson, 1990; Collett, 1991). The corresponding analysis procedures are now easily accessible via well known statistics software packages such as SPSS, GENSTAT or SAS. All analyses within the FSIPM Project were undertaken using GENSTAT 5, Release 4.1.

Typically, a statistical model aims to explain the variation in the response variate by a number of factors and covariates. The IPM interventions are factors that are included in the

Table 2. Mean percentage of plants per plot killed by *Alcidodes* and by all other causes (raw data), 1996/97

Treatment factor		Stem/ root rot	Beanfly	*Alcidodes*	All causes
Seed dressing	0 = no	0.69	0.31	3.1	6.3
	1 = yes	0.83	0.04	1.0	3.2
Earthing	0 = no	0.86	0.24	2.1	5.1
	1 = yes	0.65	0.10	2.0	4.3
Mulching	0 = no	0.92	0.11	2.2	4.3
	1 = yes	0.46	0.29	1.7	5.5
Variety	Chimbamba	1.16	0.28	2.3	6.4
	Kaulesi	0.36	0.07	1.7	3.1
Plant density	Low	0.76	0.26	1.5	3.5
	High	0.76	0.09	2.6	5.9

model. Covariates are additional variates measured on each experimental unit (e.g. soil nutrient measurements). Since variation between experimental units (generally the farmers' plots in FSIPM Project trials) tends to be quite large in on-farm trials, controlling for some of this variability by information on additional covariates leads to greater precision in treatment comparisons.

The analysis procedure determines whether the variation caused by a particular IPM intervention is larger than can be accounted for by chance (random/residual) variation alone. This in turn requires that the data presented for analysis are adequate to provide a reasonably precise estimate of the true residual variation in the data, i.e. the variation that would result if all experimental units were treated under identical conditions. Terms are included in these models to explain all known sources of variation so that the true effect of each intervention treatment can be investigated free from the influence of such sources of variability. In the reporting of statistical results, mean values are, therefore, often presented as 'predicted proportions' or 'adjusted means'. These are model-based estimates that reflect the true effect of the interventions being investigated.

RESULTS CONCERNING THE BEAN CROP – 1996/97 MAIN INTERCROP TRIAL

Main findings from the summer crop of beans (1996/97)

- Only five plots out of 48 had any plant deaths associated with BSM. No formal analysis of BSM incidence and severity was, therefore, carried out.
- From Table 2 it can be seen that plant deaths due to *Alcidodes*, as a proportion of the initial plant stand, did not exceed 5% in any of the three areas in the trial, i.e. Chiradzulu uplands, Matapwata uplands and Matapwata *dambo*. There was some evidence (P=0.025) that variety Kaulesi had lower plant deaths due to *Alcidodes* than variety Chimbamba. There was also some evidence that seed dressing with Sevin reduced the proportion of plant deaths by *Alcidodes* from about 3% to 1%.
- Overall plant mortality (due to all causes) as a proportion of the initial plant stand varied significantly (P=0.0014) between varieties Kaulesi (8%) and Chimbamba (3%) (from modelled data). There was some evidence that plant mortality was reduced from about 6% to 3% with the use of Sevin as a seed dressing for beans (P=0.032).
- The maximum number of live plants over the season varied significantly with seed dressing, with planting density and with field type. Interactions between these factors were also significant. The seed dressing effect, which resulted in greatly reduced germination, was quite marked in Matapwata *dambo* and upland fields but was less so in Chiradzulu upland fields. In Matapwata *dambo*, live plants reduced by about 52% (P<0.001) with the application of seed dressing. In Matapwata upland fields the reduction was greater (74%), while in Chiradzulu upland fields the reduction in live plants was about 15% (P=0.035).
- The reduction in live plants with the application of seed dressing with Sevin led to reduced seed weights obtained at harvest. The data were analysed on the log scale. Hence results are presented in Tables 3 and 4 on the logarithmic scale as well as on the re-transformed scale to the original units (kg/ha). Table 3 shows a significant reduction in mean seed weight with the application of seed dressing in Matapwata upland fields (P=0.002) and in Chiradzulu upland fields (P=0.038). In Matapwata *dambo* there is insufficient evidence of a seed dressing effect (P=0.827) despite the 50% reduction in live plants under seed dressing.

Table 4 presents mean seed weights for each planting density used in the trial. Although yields are higher (as expected) with the higher planting density, the increase in yields from 20 kg/ha at the lower planting density to 38 kg/ha at the higher planting density is not significant (P=0.140).

Main findings from the relay crop of beans (1996/97)

A relay crop of beans was planted in Matapwata *dambo* and upland fields of the same farmers who participated in

Table 3. Mean seed weight by seed dressing application 1996/97: (a) on a log scale; (b) kg/ha on original units

Treatment factor	Matapwata *Dambo*	Matapwata Upland	Chiradzulu Upland
(a)			
No seed dressing	2.374	4.445	4.428
	(1.40,3.35)*	(3.54,5.35)	(3.58,5.27)
Seed dressing with Sevin	2.530	1.915	3.159
	(1.46,3.60)	(0.72,3.11)	(2.32,4.00)
P	0.827	0.002	0.038
(b)			
No seed dressing	10.7	85.2	83.8
	(4.1,28.5)	(34.5,211)	(35.9,194)
Seed dressing with Sevin	12.6	6.8	23.5
	(4.3,36.6)	(2.1,22.4)	(10.2,54.6)
P	0.827	0.002	0.038

*95% CI in parentheses.

Table 4. Mean seed weight by planting density, 1996/97: (a) on a log scale; (b) (kg/ha) on original units

Treatment factor	Matapwata *Dambo*	Matapwata Upland	Chiradzulu Upland
(a)			
Low density	2.182	2.981	3.570
	(1.39,2.97)*	(2.14,3.83)	(2.86,4.28)
High density	2.762	3.561	4.150
	(1.94,3.59)	(2.77,4.35)	(3.44,4.86)
(b)			
Low density	8.9	19.7	35.5
	(4.0,19.5)	(8.5,46.1)	(17.5,72.2)
High density	15.8	35.2	63.4
	(7.0,36.2)	(16.0,77.5)	(31.2,129)

*95% CI in parentheses.

the main intercrop trial. The same set of five treatment factors were included in this relay trial. Thirty-two farmers participated in the trial, but data on yields were missing for one *dambo* farmer and one upland farmer. The main findings, using results from the remaining 30 farmers, were as follows.

- Total plant mortality, as a proportion of the initial plant stand, was found to vary significantly across the two villages participating in the trial (P=0.027) as well as across the two varieties (P=0.003). In Kambuwa village the predicted percentage of plant deaths was about 73%, while in Magomero, it was lower at about 54%. Variety Kaulesi performed better than variety Chimbamba. The percentage of deaths for Chimbamba was about 77%, but for Kaulesi about 50%.
- There was some evidence that the use of *kaselera* ridges significantly reduced bean seed weight from about 32 to 3 kg/ha (P=0.043). On the other hand, unlike in the main intercrop trial, the use of seed dressing with Sevin significantly increased bean yields from about 6 to 32 kg/ha (P=0.043). There was insufficient evidence to demonstrate a difference in seed weight between the two bean varieties (P=0.946).
- In the relay trial half of the plots did not produce any yield. The analysis was also repeated with plots which gave non-zero yields. Here again, seed dressing with Sevin was found to be beneficial. The increase in yield, after allowing for variation due to the use of *kaselera* ridges was 46 kg/ha (SE = 21.9 on 10 d.f.).

Overall conclusions from the 1996/97 trial

Sevin proved to have a deleterious effect on bean plants and was therefore abandoned. Mulching was poorly applied due to shortage of dry plant materials. It was easily displaced by wind and rain, and was found to harbour pests including the dusty brown beetle. Farmers disliked mulching because of labour costs, among other reasons (Jere, 1997). Earthing up was also regarded as laborious; in an intercrop there is already a standard banking procedure for maize, and farmers do not want to do both. High bean-planting density is costly in seed and labour and did not give significantly better yields compared to the lower planting density. Variety Kaulesi performed slightly better than Chimbamba but was also found to be fast-maturing – a characteristic greatly prized by farmers. Accordingly, only varietal tolerance was planned for investigation in the 1997/98 trials. Experimental design aspects and results from the 1997/98 trials are discussed in the following section.

DESIGN ASPECTS AND RESULTS FROM THE 1997/98 AND 1998/99 MAIN INTERCROP TRIALS

Two crops of beans were planted in 1997/98. The first was planted in November and harvested in March, and the second was a relay crop planted in April and harvested in June. Relay beans are grown only in Matapwata, so the relay trial was conducted only with Matapwata farmers. Results of these two trials are detailed separately below. Varietal tolerance was the only treatment factor included in the 1997/98 main intercrop trial as an IPM intervention for the control of BSM. This treatment factor was one of four factors tested in the trial in relation to the three intercrops: maize, bean and pigeonpea. For the management of whitegrubs in maize, one factor (seed dressing with Gaucho) was used; for the control of termites, one factor (*mbwera* or no *mbwera*) was used in Matapwata, and one factor (weeding with banking or weeding without banking) in Chiradzulu North. The fourth treatment factor was for pigeonpea: varietal tolerance with four pigeonpea varieties. A full description of the treatment factors and the (unrandomized) design layout is given by Abeyasekera *et al.*, p. 28. With respect to banking and the use of *mbwera*, farmers deviated from the planned treatment structure. Abeyasekera *et al.* (p. 28) present the full treatment struc-

Table 5. Distribution of farmers in the 1997/98 season across villages and land types

Land type (zone)	Chiradzulu		Matapwata		
	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	11	6	8	5	30
Upland	5	12	7	7	31
Total	16	18	15	12	61

Table 6. Bean variety performance on the basis of usable seed weight (kg/ha), 1997/98 summer

	Chiradzulu		Matapwata		Variety
Variety	*Dambo*	Upland	*Dambo*	Upland	Mean
Kaulesi	193.2	334.3	56.6	51.8	172.6
Nagaga	145.5	318.0	14.4	38.2	142.7
Napilira	162.7	278.2	26.1	0.0	129.1
Kalima	163.1	361.3	31.9	81.5	173.3

ture, as actually applied, with treatment combinations assigned randomly to individual farms.

Sixty-one farmers were included in the 1997/98 main intercrop trial. Most of these farmers (approximately 82%) were those who had participated in the 1996/97 main intercrop trial. Each of the farmers participating in the 1997/98 trial had four plots on his/her farm, with each plot having one of the proposed treatment combinations. The trial layout was such that each farmer grew each of the four bean varieties and each of the four pigeonpea varieties. Two of their plots had each level of the maize treatment factors. The distribution of farmers across zones, villages and EPAs is shown in Table 5.

Three yield responses were considered for comparing yield performance across the four bean varieties in each of the two seasons. These were:

- usable seed weight (kg/ha) adjusted for moisture content
- total pod weight (kg/ha)
- number of plants with pods from the net plot at harvest.

In the 1997/98 season, maize seed dressing and banking were additional treatment factors. In the analysis, the variation in bean yields according to variety and according to seed dressing and banking was investigated. The interactions between the three treatment factors and their possible interactions with zone and EPA differences were also investigated. Banking was generally always practised in Chiradzulu *dambo* areas, so the analysis involving banking was restricted to the remaining areas.

A similar trial was conducted in the 1998/99 season with 40 of the farmers who participated in the previous season. Again the same four bean varieties were included, one on each of four plots per farm. However, there was no application of seed dressing for maize within the intercropping system and farmers banked all their plots.

Table 7. Mean usable seed weight (kg/ha) by level of seed dressing and EPA, 1997/98 summer

Seed dressing	EPA		Overall seed dressing effect
	Chiradzulu	Matapwata	
No	271 (n=66)	39 (n=52)	169
Yes	222 (n=66)	35 (n=52)	140
Overall EPA effect	247 (n=132)	37 (n=104)	P for difference between seed dressing levels = 0.012
P for difference between EPAs <0.001			

Yield responses from the 1997/98 and 1998/99 seasons

Usable seed weight (kg/ha)

Results from the 1997/98 summer beans

In the analysis, significant differences were found between the bean varieties with respect to the amount of usable seed weight (kg/ha) produced (P=0.010). Application of seed dressing on maize tended to depress bean yields (P=0.012), possibly due to the increase in maize yields competing with the beans. There was insufficient evidence of a variety by seed dressing interaction (P=0.916), or of an effect due to banking (P=0.485). There was some evidence of a seed dressing by EPA interaction (P=0.050) and a possibility that the bean variety performance varied across zones (P=0.059). The results are summarized in Tables 6 and 7.

There were clear differences between EPAs (P<0.001) and zones (P<0.001). Upland yields were higher than in *dambo* areas by about 135 kg/ha. Matapwata yields were extremely poor at about 37 kg/ha (SE = 13.6). In contrast, the yield performance in Chiradzulu was much higher at about 247 kg/ha (SE = 11.7) (Table 7).

Table 8. Mean seed weight means according to varieties and zones, 1997/98 winter

Variety	*Dambo*	Upland
Kaulesi	10.78	11.59
Nagaga	12.78	2.18
Napilira	15.18	11.76
Overall means	12.43	9.46
P	0.656	0.017

Table 9. Bean variety performance on the basis of usable seed weight (kg/ha), 1998/99 summer

	Chiradzulu		Matapwata		
Variety	*Dambo*	Upland	*Dambo*	Upland	Variety mean
Kaulesi	120.2	218.0	55.7	65.6	128.6
Nagaga	120.5	216.1	53.8	63.6	127.7
Napilira	117.9	213.4	51.1	61.0	125.1
Kalima	116.5	212.0	49.7	59.6	123.7

Results from the 1997/98 winter beans

Of the farmers included in the main intercrop trial in Matapwata, 27 participated in the relay bean trial. However one farmer, Bambo Tomato, in an upland farm in village Kambuwa, growing Kaulesi and Napilira, had all his plants destroyed by goats. So data for analysis came from the remaining 26 farmers. Each farmer grew either the bean varieties Kaulesi and Nagaga, or the varieties Kaulesi and Napilira on two of their plots.

Analysis of variance (ANOVA) procedures were carried out to investigate the influence of seed dressing and varieties on total seed weight (kg/ha), allowing for variation between farmers. There was insufficient evidence of a seed dressing effect (P=0.551) or of an overall effect due to varieties (P=0.110). The analysis did not indicate that variety differences varied across zones (P=0.112). However the predicted yields showed the possible existence of variety differences in the uplands. The analysis was repeated, therefore, for *dambo* and uplands separately. There was little indication of a variety difference in *dambo* areas (P=0.656); however in the uplands there was some evidence of a difference (P=0.017), the analysis being carried out on a log scale because of departures from the variance homogeneity assumption in the ANOVA. The results summarized in Table 8 are given in the same units as the raw scale of measurement.

Results from the 1998/99 season

Forty farmers participated in the main intercrop trial in 1998/99. The analysis of data on usable seed weight did not reveal any significant differences between the bean varieties. There were, however, clear differences between EPAs (P=0.006), with the yield performance in Matapwata EPA being very poor as was the case in the previous year. There was some indication of a possible upland versus *dambo* difference (P=0.076). There was no evidence of a land type by EPA interaction (P=0.220). Results are shown in Table 9.

Total pod weight (kg/ha)

Results from the 1997/98 summer season

Analysing data on total pod weights gave results similar to those found for usable seed weight. The results are shown in Tables 10–12. Banking effects were not evident (P=0.688). Application of seed dressing significantly reduced bean yields (P=0.004) and there was some evidence of a seed dressing by EPA interaction (P=0.024). Differences between bean varieties with respect to pod weights were not so clear (P=0.073), but there was some evidence of an interaction with zone (P=0.031). With Kaulesi and Napilira, the difference between upland and *dambo* pod weights were about 65 kg/ha, but for Nagaga and Kalima the differences were higher – more than 150 kg/ha.

There was strong evidence of an interaction between zones and EPAs (P<0.001). From Table 12 it can be seen that this is due to *dambo* versus upland differences being negligible in

Table 10. Bean variety performance on the basis of total pod weight (kg/ha), 1997/98 summer

	Zone		
Variety	*Dambo*	Upland	Means
Kaulesi	300	358	330
Nagaga	187	345	268
Napilira	230	299	265
Kalima	192	405	300
Overall zone effects	227	352	*P* for difference between variety means = 0.073
P for difference between zones <0.001			

Table 11. Predicted mean pod weight by level of seed dressing and EPA, 1997/98 summer

	EPA		
Seed dressing	Chiradzulu	Matapwata	Overall seed dressing effect
No	518	70	321
Yes	416	63	260
Overall EPA effect	467	66	*P* for difference between seed dressing levels = 0.004
P for difference between EPAs <0.001			

Table 12. Predicted mean pod weight by level of zone and EPA, 1997/98 summer

	EPA		
Zone	Chiradzulu	Matapwata	Overall means
Dambo	358	67	227
Upland	570	66	352
Means	467	66	291

Table 13. Total pod weight means according to varieties and zones

Variety	*Dambo*	Upland
Kaulesi	21.3	40.4
Nagaga	26.0	5.7
Napilira	26.9	28.5
Overall means	23.9	29.2
P	0.803	<0.001

Table 14. Bean variety performance on the basis of total weight (kg/ha), 1998/99 summer

	Chiradzulu		Matapwata		
Variety	*Dambo*	Upland	*Dambo*	Upland	Variety mean
Kaulesi	199	393	120	141	227
Nagaga	177	360	99	119	200
Napilira	166	361	87	108	194
Kalima	171	366	92	113	199

Matapwata but much higher, by over 200 kg/ha, in Chiradzulu.

Results from the 1997/98 winter season

Results from the winter season beans for total pod weight were similar to those for total seed weight (kg/ha). Overall seed dressing and variety effects were non-significant (P=0.687 and 0.090, respectively). The P value for the zone by variety interaction was 0.070, possibly indicating that variety effects differed across zones, and further analysis demonstrated that this was indeed so. In *dambo* areas there was little evidence of a difference (P=0.803), but in the uplands there were clear differences between varieties (P<0.001), the analysis again being based on a log scale. The results are presented in Table 13 and show that in the uplands Kaulesi gives means that are about seven times higher than Nagaga, and about 1.5 times higher than Napilira. (P<0.001 and P=0.009, respectively).

Results from the 1998/99 summer season

The analysis of pod weights gave results similar to those for usable seed weight. There was no evidence of a difference between varieties. Upland yields were significantly better than *dambo* yields (P=0.028), and Chiradzulu yields were better than Matapwata yields (P=0.011). The results appear in Table 14.

Table 15. Predicted mean number of plants with pods (per plot) by zone and EPA

	EPA		
Zone	Chiradzulu	Matapwata	Overall means
Dambo	109 (n=64)	35 (n=52)	76
Upland	122 (n=68)	43 (n=52)	88
Means	116 (n=132)	39 (n=104)	82

Numbers of plants with pods

Results from the 1997/98 summer season

Modelling procedures undertaken with respect to the numbers of plants with pods showed no evidence of an effect due to any of the treatment factors. Significance probablities associated with these factors were P=0.927 for seed dressing, P=0.332 for banking, and P=0.984 for bean variety differences. However, as for usable seed weight and total pod weight, there was strong evidence of an EPA difference (P<0.001) with Matapwata doing very poorly, and strong evidence of a difference between *dambo* and upland areas with mean numbers of plants with pods being higher in the uplands compared to *dambo* areas. There was no evidence of a zone by EPA interaction (P=0.118). The results are shown in Table 15.

Results from the 1997/98 winter season

The results are similar to those given above: Nagaga yields are high in *dambo* but do not differ significantly from those of Kaulesi and Napilira (P=0.293). However, the mean number of plants with pods for Nagaga is significantly lower than for the other two varieties in the uplnds (P=0.002). This results in a significant interaction effect between zones and varieties (P=0.010). The predicted values for the mean number of plants with pods are shown in Table 16.

Results from the 1998/99 summer season

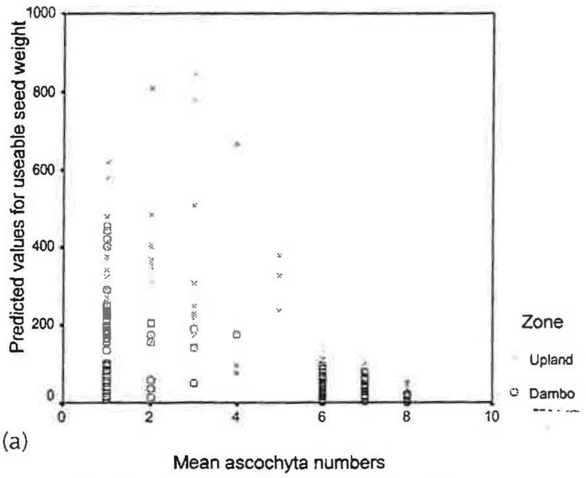
Mean numbers of plants with pods varied significantly across varieties, (P=0.024) with Kaulesi giving significantly higher numbers. There were no differences among the other three varieties (Table 17). As with usable seed weight and total pod weight, there was some evidence of EPA differences (P=0.051) and a possible effect due to zones (P=0.057). There was also a significant zone by variety interaction, largely due to Nagaga performing better than Napilira in the uplands (P=0.003), whereas in *dambo* it performed as badly, as did Napilira.

Table 16. Predicted mean values for the number of plants with pods

Variety	*Dambo*	Upland
Kaulesi	45.5	68.1
Nagaga	68.1	15.4
Napilira	57.0	60.4
Means	53.8	53.9
P	0.293	0.004

Table 17. Bean variety performance on the basis of the number of plants with pods, 1998/99

	Chiradzulu		Matapwata		
Variety	*Dambo*	Upland	*Dambo*	Upland	Variety mean
Kaulesi	61.6	84.3	48.3	52.5	64.0
Nagaga	46.5	87.9	32.1	57.7	55.5
Napilira	51.5	66.3	37.1	34.4	50.7
Kalima	50.1	76.7	35.7	44.8	53.8



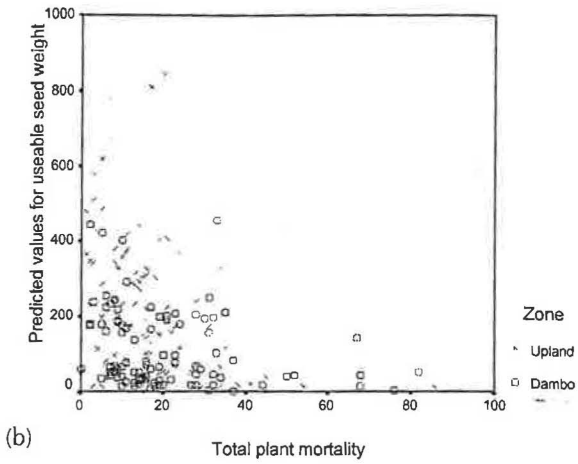


Figure 1. Predicted mean values for seed weight versus (a) Ascochyta *numbers and (b) total plant deaths.*

Main findings concerning pest damage in the 1997/98 and 1998/99 seasons

Presence of Ootheca *(1997/98 summer season)*

All research plots were affected by *Ootheca* occurrence in Matapwata. However, in Chiradzulu only about 60% of plots were affected. Seed dressing and banking appeared to have no effect on the presence of *Ootheca*. There was a possible marginal effect (P=0.075) across varieties, with the incidence being slightly higher for Kaulesi and Nagaga (chance of occurrence about 30%) compared to Napilira and Kalima (chance of occurrence about 26%). The chance of occurrence of *Ootheca* across the four varieties is shown in Table 18.

Presence of nematodes (1997/98 summer season)

Nematode occurrence was higher in Matapwata than in Chiradzulu, but the mean nematode score on a 0–10 scale was extremely low. All mean scores were below 0.5 in Chiradzulu and below 2.0 in Matapwata. There was evidence that nematode occurrence increased with banking (probability of occurrence 0.4 compared to 0.3 without banking), but this is unlikely to be of practical significance.

Table 18. Probability of *Ootheca* occurrence under each bean variety

Variety	Probability of *Ootheca* occurrence
Kaulesi	0.323
Nagaga	0.323
Napilira	0.265
Kalima	0.265
P	0.075

Damage by stem/root rot, cutworms, BSM, Alcidodes *etc. (1997/98 summer season)*

Damage to beans due to stem/root rot, cutworms, BSM, *Alcidodes* and others was extremely low. Significant differences across banking levels and varieties were found for stem/root rot, across seed dressing levels for BSM, and across banking levels and varieties for *Alcidodes*. However, it is important not to place too much emphasis on these results as the overall incidence is so low. The occurrence of a significant result in itself does not imply that the results are of practical importance. Damage incidence here has been modelled in terms of the proportion of plants showing an incidence, and the large denominator used in calculating this proportion gives a high sample size which results in (apparently) strong evidence of a significant effect. These results must, therefore, be interpreted with some caution.

Influence of damage parameters on yield parameters (1997/98 summer season)

Of all the damage variables recorded and analysed, only *Ascochyta* scores and total plant mortality appeared to have a significant influence on usable seed weight (P<0.001 and P=0.023, respectively). The latter result is expected, but corresponding visual displays (Figure 1) demonstrate that the effects were not clearly obvious.

Damage by BSM from results of the winter bean crop (1997/98)

The mean number of BSM found in the 10 live plants selected at harvest time for laboratory examination (Table 19) showed a significantly higher incidence for Nagaga compared to Kaulesi and Napilira. The difference in means between BSM numbers for Kaulesi and Nagaga was about 8.6 (SE = 1.7), while the difference in mean BSM for Napilira and Nagaga was about 8.4 (SE = 1.5).

The mean number of plant deaths per plot by BSM during

Table 19. Mean number of BSM found in 10 live plants at harvest

Variety	Mean BSM	Zone	Mean BSM
Kaulesi	12.5	*Dambo*	13.9
Nagaga	21.1	Upland	17.0
Napilira	12.7		
P	<0.001	*P*	0.174
SED	1.69	SED	2.23

Table 20. Predicted probabilities of BSM occurrence in live bean plants at harvest

Variety	Prob. BSM	Zone	Prob. BSM
Kaulesi	0.69	*Dambo*	0.70
Nagaga	0.82	Upland	0.75
Napilira	0.71		
P	0.008	*P*	0.168

Table 21. Predicted probabilities of plant death due to BSM based on season's data

Zone	Kaulesi	Nagaga	Napilira	Total
Dambo	0.299	0.208	0.276	0.27
Upland	0.385	0.219	0.530	0.39
Overall prob.	0.34	0.21	0.40	

the season (Figure 2) showed a slight rise in the middle of the season for Kaulesi and Napilira, followed by a dramatic rise in early May. For Nagaga, however, the mean number of plant deaths per plot per sampling occasion was generally uniform over the season, and significantly lower overall than in the other two varieties.

The predicted probability of infestation due to BSM (Table 20), based on the number of infested plants out of 10 live plants selected at harvest time, was highest for Nagaga (P=0.82) compared to Kaulesi (0.69) and Napilira (0.71). These figures are much higher than the corresponding probabilities of death estimated over the entire season (0.21 to 0.53, see Table 21). The former was based on laboratory examination of live plants, the latter on field records of BSM incidence in dead plants. It appears that Nagaga supports higher numbers of BSM without succumbing, thus developing high scores, while the other varieties limit their BSM load by dying. It is possible that Nagaga is intrinsically more attractive to BSM than the other varieties.

Predicted probabilities of plant deaths due to *Alcidodes* showed insufficient evidence of a difference across zones. There was some evidence of an overall variety difference, with Nagaga having the smallest chance of *Alcidodes* incidence. The chances of incidence were much greater in *dambo* than in uplands. Overall *Alcidodes* incidence was, however, very low. So variety differences with respect to *Alcidodes* may have little practical value.

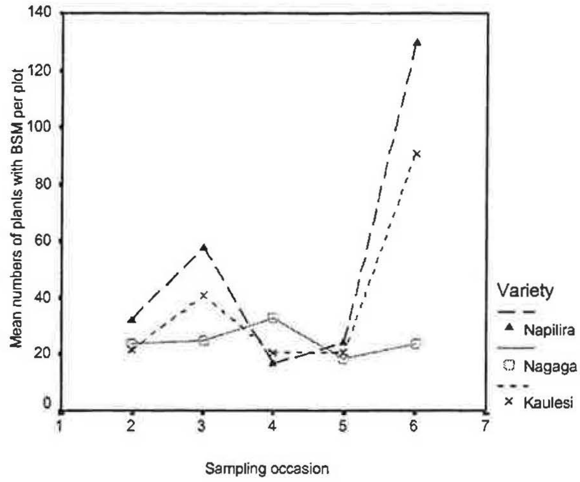


Figure 2. Mean numbers of dead plants per plot with BSM across sampling occasions.

Damage during the 1998/99 summer season

In the 1998/99 summer season, damage by BSM and by cutworms was very low. In Chiradzulu there were no plant deaths at all due to these two causes; in Matapwata there were 5 plant deaths due to cutworms and 35 due to BSM. The latter 35 were distributed amongst the four bean varieties as 3 deaths in plots growing Kaulesi, 13 in plots growing Nagaga, 13 in plots growing Napilira, and 6 in plots growing Kalima. Since these frequencies are very small, no further analysis was carried out on plant deaths due to these two causes.

In comparison, there were substantial numbers of plant deaths due to stem/root rot, *Alcidodes* and *Sclerotium* in both Chiradzulu and Matapwata, and in addition some plant deaths due to bacterial blight in Matapwata.

The total numbers of plants dead due to these causes over the entire season, as a proportion of the germinating plant stand, were modelled using a generalized linear model with a binomial error structure. There were significant differences between *dambo* and upland areas for all these damage parameters. The incidence levels were higher in *dambo* than in upland for stem/root rot, *Alcidodes* and *Sclerotium* in Chiradzulu. Incidence in *dambo* Matapwata was slightly greater than in upland Matapwata for stem/root rot, but for *Alcidodes*, *Sclerotium* and bacterial blight upland incidence was greater than in the *dambo*. The results are summarized in Tables 22–25. It will be noted that results are not consistent across the two EPAs.

With respect to stem/root rot, significant differences between varieties are due to Kalima having higher damage incidence in Chiradzulu (2.3%) compared to the other three varieties (around 1.5%), while in Matapwata, Nagaga has the lowest incidence (0.4%) compared to the other three varieties (1.0%).

Alcidodes incidence is high for Kaulesi and Nagaga, compared to Kalima and Napilira.

Sclerotium incidence is extremely low in Chiradzulu, and

Table 22. Percentage of plant deaths (*n* = germinating stand) due to stem/root rot in the 1998/99 summer season

	Chiradzulu		Matapwata			
Variety	*Dambo*	Upland	*Dambo*	Upland	Chiradzulu	Matapwata
Kaulesi	2.1	0.5	1.1	0.3	1.6	0.8
Nagaga	2.6	0.7	0.6	0.1	1.9	0.4
Napilira	1.8	0.4	0.9	1.2	1.3	1.1
Kalima	3.2	0.8	1.1	0.2	2.3	0.8
P					0.028	0.039

Table 23. Percentage of plant deaths (*n* = germinating stand) due to *Alcidodes* in the 1998/99 summer season

	Chiradzulu		Matapwata			
Variety	*Dambo*	Upland	*Dambo*	Upland	Chiradzulu	Matapwata
Kaulesi	4.0	0.6	4.4	5.6	2.8	4.9
Nagaga	5.8	0.8	2.6	3.3	4.1	2.9
Napilira	2.5	0.3	1.0	1.3	1.8	1.1
Kalima	1.7	0.2	1.9	2.3	1.2	2.1
P					<0.001	<0.001

Table 24. Percentage of plant deaths (*n* = germinating stand) due to *Sclerotium* in the 1998/99 summer season

	Chiradzulu		Matapwata			
Variety	*Dambo*	Upland	*Dambo*	Upland	Chiradzulu	Matapwata
Kaulesi	0.8	0	1.1	0.3	0.5	1.8
Nagaga	1.6	0	0.6	0.1	1.0	2.1
Napilira	1.1	0	0.9	1.2	0.8	2.5
Kalima	0.5	0	1.1	0.2	0.3	1.8
P					0.008	0.328

Table 25. Percentage of plant deaths (*n* = germinating stand) due to common bacterial blight, 1998/99 summer season

	Matapwata		Damage percentage
Variety	*Dambo*	Upland	by variety
Kaulesi	1.0	1.3	1.1
Nagaga	0.6	1.4	0.9
Napilira	1.2	4.7	2.6
Kalima	4.1	2.5	3.4
P			<0.001

higher in Matapwata (2%), but there is no evidence that incidence levels vary across varieties.

Bacterial blight is present only in Matapwata and has significantly higher levels of incidence under varieties Napilira and Kalima compared to Kaulesi and Nagaga.

Overall, the level of incidence, as measured by the number of plant deaths as a proportion of the initial germination stand, is less than 5% due to any of the different causes of death for any of the varieties. No variety is consistently the best performer with respect to all pest and disease causes.

FARMER EVALUATION SURVEY IN MATAPWATA AND MOMBEZI EPAs, MAY/JUNE 1998

A farmer evaluation survey was carried out during May/June 1998 using a pre-tested questionnaire with a view to determining current practices adopted by farmers and their opinions and perceptions concerning pests and other problems. A total of 40 farmers were interviewed, selected from the 60 farmers participating in the on-farm experimental trial. This brief report summarizes the findings from the survey with respect to the bean crop grown as an intercrop with maize.

General problems perceived by farmers

Farmers were asked to state the most serious problems they faced with respect to the growth of beans. The problem stated

Table 26. Farmers' most serious general problems

Problem	Frequency	Percentage
Wilting	11	27.5
Too much rain	8	20.0
Pod rot	7	17.5
Stem rot	6	15.0
Burning of leaves	4	10.0
Too hot	1	2.5
Drying of flowers	1	2.5
No problem identified	2	5.0
Total	40	100

most frequently as the most serious was 'wilting' (27.5%), followed by 'too much rain' (20%). Stem rot and pod rot were also regarded as the most serious problem by some farmers (Table 26).

Pest-related problems perceived by farmers

Only 25 farmers spontaneously mentioned one or more pests as being a problem. *Ootheca* featured most frequently in their responses. Other pests mentioned by at least two farmers were sucking bugs, whitegrubs, aphids, elegant grasshoppers, caterpillars, *Alcidodes* and pod borers. Farmers were also asked which pest was most serious overall. The results in Table 27 show that the most serious pest was *Ootheca* (for 35% of the farmers interviewed), followed by pod borers (for 25% of the farmers). For three of the farmers the question of the most serious pest was unknown or not relevant.

Farmers' opinions about bean varieties

Farmers were asked what qualities they looked for in a bean variety. They were then prompted with a list of other criteria which they had not mentioned spontaneously but which might be of importance, and asked to score their own and the research varieties against any criteria they rated as important.

Yield, speed of maturation and taste featured highest among the criteria that farmers judged as important in evaluating bean varieties. Half the farmers interviewed gave yield as the first criterion of importance, while 40% gave speed of maturity as their first or second criterion. Taste, marketability and cooking time also featured prominently among criteria mentioned spontaneously as important. At least 20% of farmers mentioned these five criteria.

When asked about criteria that had not been mentioned spontaneously, only six farmers declared any as being unimportant. These were the number of beans in the pod (two farmers), marketability (one farmer), taste (one), cooking time (one) and tolerance to excessive rain (one). Farmers were unanimous in viewing yield, speed of maturation, pest resistance and disease resistance as important in evaluating bean varieties.

Table 27. Farmers' perceived most serious pest problems

Problem	Frequency	Percentage
Ootheca	14	35.0
Pod borers	10	25.0
Sucking bugs	3	7.5
Whitegrubs	2	5.0
Aphids	2	5.0
Snails	2	5.0
Elegant grasshopper	1	2.5
Caterpillar	1	2.5
Alcidodes	1	2.5
Bean stem maggot	1	2.5
No problem identified	3	7.5
Total	40	100

Comparison of varieties according to farmers' evaluations

In the survey farmers were asked to evaluate each of the research varieties (Kaulesi, Kalima, Nagaga and Napilira) as well as the varieties they themselves had planted in the current year. The evaluation was made with respect to all criteria that the farmer regarded as being important in assessing bean varieties. It was based on a score of 1–5, with 1 = very poor and 5 = very good.

Table 28 shows bean varieties grown by farmers in their own fields and evaluated by the farmer during the survey. Chimbamba is seen to be the most commonly grown variety amongst the farmers, followed by Kaulesi.

A comparison was made across the varieties in order to determine whether differences in mean scores between varieties reflect chance variation or demonstrate a real difference in the evaluations given by the farmers. The standard statistical procedure for comparing variety means in this situation is the two-way ANOVA which allows an adjustment for the farmer-to-farmer variation and gives a more meaningful comparison across the bean varieties. The procedure assumes a continuous-scale normal distribution for the mean scores under each variety. This assumption is reasonable if the number of farmers, whose evaluations are used in calculating the means, is sufficiently large. With a smaller

Table 28. Bean varieties grown by farmers in their own fields

Variety	Frequency	Percentage
Chimbamba/Zofiira	25	62.5
Zoyera	3	7.5
Small white	0	0.0
Yellow	1	2.5
Kaulesi (farmer)	14	35.0
Nanyati (Dwarf)	8	20.0
Nanyati (Climber)	0	0.0
Nambewe	0	0.0
Kalima (farmer)	2	5.0
Khaki	1	2.5
Golomondo	1	2.5

Table 29. Mean values for each of five indices showing farmer preferences across five bean varieties

	Index				
Variety	1	2	3	4	5
Kaulesi	4.42	4.60	4.43	4.52	4.08
Chimbamba	3.24	3.28	3.13	3.14	3.18
Nagaga	2.59	2.63	2.50	2.51	2.35
Kalima	2.39	2.40	2.24	2.25	2.11
Napilira	2.22	2.20	2.21	2.22	2.10

number of farmers the assumption of normality is likely to be violated as the raw data, i.e. the evaluation scores themselves are non-normal since they can take only the distinct set of values 1, 2, 3, 4 and 5.

In this study the sample size is quite adequate, with 40 farmers providing evaluations. A two-way ANOVA was therefore performed to compare varieties on the basis of the four criteria that most farmers found important: yield, speed of maturation, marketability and taste. Mean evaluation scores on the basis of taste did not differ significantly across the five varieties. However, for each of the remaining criteria there was clear evidence of a preference for Kaulesi, followed by Chimbamba. There was insufficient evidence to indicate any differences in preference between the remaining three varieties (Kalima, Nagaga and Napilira).

Indices to compare farmers' overall preference

There are two ways to determine which varieties overall are most preferred by farmers. The simplest is to ask the farmers directly, and this was done in the survey discussed here. One disadvantage with this approach is the difficulty of interpreting the resulting information as different farmers may be thinking of different criteria when they give their answer. If farmers have already been through a scoring exercise to evaluate each variety on the basis of several criteria, then a procedure which controls this problem is to combine, across the different criteria, the evaluation scores given by each farmer under each criterion they thought important. A simple average is very limited as it gives equal weight to each of the criteria, including those that the farmer declared to be important only when her/his attention was drawn to them. It is more meaningful to give a greater weight to criteria that a farmer spontaneously declared as important than those that were later suggested as additional criteria to consider.

Thus, in order to determine an overall comparison between the five varieties, the evaluation scores need to be combined across the criteria on which the scores were based. For this purpose, four different indices were computed so that each index weighted the evaluation scores for a set of criteria in a different way. The four indices comprised all combinations of two classifications, each classification having two alternatives, say (a) or (b). The first classification corresponded to the set of criteria used, while the second classification corresponded to the method of weighting used. The full list of criteria considered in the first classification

Table 30. Specific comparisons among the five bean varieties for index 4

Comparison	Difference in means	SED	*P*
Kaulesi compared to Chimbamba	1.38	0.222	<0.001
Chimbamba compared to Kalima, Nagaga and Napilira	0.816	0.193	<0.001
Comparisons among Kalima, Nagaga and Napilira			0.241

were: yield, speed of maturation, marketability, number of beans in pod, taste, cooking time, pest resistance, disease resistance, drought resistance, and tolerance to excessive rain. The development of the four indices is described by Abeyasekera *et al.* (in preparation).

For comparative purposes a further index was considered, i.e. an unweighted average over all criteria.

These indices, based on farmers' evaluations, were calculated, making the data amenable to standard statistical analysis procedures that apply to quantitative data even if the sample size, i.e. the number of farmers, is relatively small. This is because an index given to each farmer's set of scores gives results that provide a more variable measure having quantitative characteristics. The data can be subjected to an ANOVA to make an overall comparison among the bean varieties after allowing for possible differences between farmers.

The mean values for the five indices are shown in Table 29, and demonstrate that ranking of varieties is very consistent across the indices. Results for the unweighted average, i.e. index 5, deviate only slightly from those for the weighted indices. Generally, the unweighted index gives lower values. Looking at the weighted indices, it is observed that Kaulesi always has the highest mean index score of around 4.5 units, significantly better than the mean scores for Chimbamba which were around 3.2 units ($P<0.001$). The remaining three varieties gave mean scores between 2.2 and 2.5 units.

Specific comparisons across the five varieties for index 4 appear in Table 30. Index 4 was used as it is the simplest of the four weighted indices computationally. There were no significant differences evident among the varieties Kalima, Nagaga and Napiira ($P=0.241$) with respect to index 4, but their mean scores were significantly lower than the mean scores for Chimbamba ($P<0.001$). However, it was found for index 1 that a few farmers (about 25%) did give high scores in their evaluations of Kalima, Nagaga and Napilira.

Overall preference by direct questioning

In the survey, farmers were also asked to state their overall most preferred variety. The results are shown in Table 31. Here Kaulesi was the variety preferred by most farmers (57.5%). Four farmers (10%) gave Chimbamba as the most preferred variety, while another four liked Nagaga. Other varieties given as the most preferred were Kalima (the choice

Table 31. Farmers' overall preferred bean variety

Variety	Frequency	Percentage
Kaulesi	23	57.5
Chimbamba/Zofiira	4	10.0
Nagaga	4	10.0
Kalima	2	5.0
Napilira	1	2.5
Zoyera	1	2.5
Nanyati (Dwarf)	1	2.5
Khaki	1	2.5
Preferred variety not stated	3	7.5
Total	40	100

of just two farmers), and Zoyera, Napilira, Nanyati (dwarf) and Khaki (one farmer each time).

The overall results are very clear. Farmers in general show a strong preference for Kaulesi above Chimbamba, but clearly prefer Chimbamba above Kalima, Nagaga and Napilira. There was insufficient evidence to indicate any preference from amongst these latter three varieties.

CONCLUSIONS

Despite selection of new varieties (Nagaga and Napilira) for improved disease and pest resistance, these varieties did not yield better than the local farmers' variety (Kaulesi) under smallholder intercropping conditions, and often performed worse.

In the summer bean crop, BSM was found to be an insignificant problem, perhaps owing to a succession of wetter-than-average years. Overall, diseases were significant as a cause of plant deaths and yield losses in the summer crop owing to an unfavourable microclimate under intercropping.

Bean stem maggot remains an important pest problem in the winter crop, but increasing problems of drought caused farmers in Matapwata to lose interest in working with the relay bean crop in favour of field peas. Farmers clearly prefer Kaulesi to all other bean varieties (including Chimbamba) and prefer their most commonly grown variety, Chimbamba, to the new research varieties.

Earliness of maturity is a major preoccupation with farmers in Blantyre/Shire Highlands to provide food before the maize crop is harvested and to benefit from price premiums. Earliness is also likely to be a factor in maintaining yield levels at or above those of the improved varieties which are exposed to pests and diseases for a longer period (Orr *et al.*, 1999).

There is a clear need for initiatives to increase the supply of early maturing bean varieties in Blantyre/Shire Highlands. This would provide increased food security through earlier access to leaf relish and green beans for domestic consumption during the hungry period (January–March) as well as boosting farm household incomes.

Participatory bean breeding to improve the disease resistance and yield of early maturing varieties that are already recognized and valued by farmers would provide additional benefits to resource-poor smallholders.

The small-seeded Central American varieties (Mkhalira and Kambidzi), grown on observation plots in 1998/99 season, have been well received by farmers on grounds of taste, yield and earliness (FSIPM, unpublished data) as well as having resistance to yellow witchweed (*Alectra vogelii*; see Mainjeni and Riches, p. 226). The availability of these varieties in Blantyre/Shire Highlands needs to be increased.

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DISCUSSION

C. R. Riches. Interesting indications of the type of bean variety which farmers prefer have been shown by the farmers' plots in 1998/99. Does the Bean Programme use participatory variety selection which may allow us to arrive swiftly at the type of bean farmers want?

J. M. R. The initial selection of the bean varieties does not involve the farmers because the main emphasis of the selection process is on adaptability, yield potential, low soil fertility, disease reaction, and acceptable grain characteristics. When promising varieties have been identified they are screened in on-farm trials which are conducted by the breeder and social scientist. It is during the on-farm testing of varieties where farmers are fully involved, and the scientists also conduct the post-harvest evaluations which include many other aspects, such as cookability and farmers' preferences.

E. Chilembwe. The bean yields in your experiment were very low. Did you ask the breeder why the varieties performed poorly? What factors contributed to the low yields?

J. M. R. These varieties were mainly assessed and selected through sole crop trials. In a maize intercrop the beans were shaded, and there is a very humid microclimate which is conducive to build up of diseases, hence yields are low.

A. J. Sutherland. Does the national Bean Improvement Project select under intercropping conditions? Participatory varietal selection usually involves taking a larger number of 'promising' varieties on-farm, for example 10–15 varieties, not only three or four of the best varieties.

J. M. R. The selection of promising bean varieties initially is done under sole cropping, but in the on-farm evaluations both the testing and selection by farmers are done under intercropping systems with maize. The Bean Improvement Project endeavours to test as many promising bean varieties as possible, but the limitations of farmers' landholdings dictate that our project can test only a few varieties at a time in a season.

A. A. Chirembo. How did the project interact with the bean breeder, particularly on the yield results of the different varieties?

J. M. R. We brought the bean breeder to see the performance of Napilira and Nagaga under intercropping. He noted that Napilira particularly did not do well when grown with maize.

C. T. Kisyombe. Physiologically early maturing crop varieties are associated with low yields compared with the late maturing varieties which are high yielding. How did the yield of the early maturing variety Kaulesi compare with the yield of the late maturing, high-yielding varieties like Kambidzi and Mkhalira.

J. M. R. We did not use those two varieties, but our results show that Npilira and Nagaga did not perform as well as Kaulesi. The value of early varieties is that the yield (though not large) comes at a time when the produce is of higher value in the market, and is also needed as a source of food.

C. Mainjeni. What qualities do the varieties Mkhalira and Kambidzi have that makes them rated so highly?

J. M. R. We have only grown these beans for a single season under farmer-designed/managed plots. However, farmers rated them very highly for yield, speed of maturation, taste and cooking time.

G. K. C. Nyirenda. We are dealing with a difficult situation since beans are grown under intercropping in summer under rainfed conditions and as monocrops under relay in winter cropping. The breeder must produce varieties that do well under maize/bean intercropping and under monocropping.

Assessment of improved pigeonpea varieties under smallholder management

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ABSTRACT

This paper reports the results of researcher-designed, farmer-managed on-farm trials carried out in three seasons (1996/97, 1997/98 and 1998/99) to investigate pest management strategies against *Fusarium* wilt attacking smallholder pigeonpeas intercropped with maize. Participating farmers came from four villages within Chiradzulu and Matapwata Extension Planning Areas (EPAs) in Blantyre/Shire Highlands. The 1996/97 trial was mounted with 64 farmers in intercropped maize (MH18), bean and pigeonpea farming systems using 2 plots (each 10.8 x 10.8 m)/farm. Two pest management strategies were explored, i.e. planting position of pigeonpea (ridge top or ridge side) and varietal resistance (ICP 9145 against a local variety). Higher yields and greater resistance to *Fusarium* wilt were found with ICP 9145 compared to the local variety but the increase in yields (22 kg/ha) was not significant. Planting position had little effect. In 1997/98 and 1998/99, four varieties of pigeonpea were compared (local variety, ICP 9145, ICEAP 00053 and ICEAP 00040) using 4 plots (each 10.8 x 5.4 m)/farm on 61 farms. Yields were much higher in Chiradzulu North EPA (141 kg/ha and 210 kg/ha, respectively in 1997/98 and 1998/99) compared to Matapwata (25 kg/ha and 170 kg/ha, respectively in the two seasons). The yield performance of ICP 9145 was found to be stable over the two seasons, ranging from 100 kg/ha to about 165 kg/ha but its seed size was poor compared to the two ICEAP varieties. ICEAP 00053 gave low yields in 1997/98 (59 kg/ha), but gave better yields (214 kg/ha) in 1998/99, although there was no significant yield improvement over ICP 9145. Although ICEAP 00053 has a seed size comparable with ICEAP 00040, its high variability between years and its apparent susceptibility to *Fusarium* wilt makes it unsuitable for pigeonpea growing areas in Blantyre/Shire Highlands. ICEAP 00040 gave a consistently good yield performance over both seasons (108 kg/ha in 1997/98 and 264 kg/ha in 1998/99). It is significantly more resistant to *Fusarium* wilt than ICEAP 00053 or the local variety and the number of seeds/pod approaches levels found in ICP 9145. Acceptability by farmers and Dhal Millers Association Limited is also high. Its release in Blantyre/Shire Highlands will be a significant benefit to smallholders in this area.

INTRODUCTION

The Farming Systems Integrated Pest Management (FSIPM) Project, conducted in the Blantyre/Shire Highlands Rural Development Project area of Blantyre Agricultural Development Division in southern Malawi, aimed to provide small-scale resource-poor farmers with acceptable and sustainable IPM strategies that reduce crop losses by pests and diseases. Following a Stakeholder Workshop in June 1996, Chiradzulu and Matapwata Extension Planning Areas (EPAs) were selected as sites for the project and farmers with a maize/bean/pigeonpea intercropping system were identified for the main on-farm experimental trials. Diagnostic surveys and farmer focus group discussions were used to target priority pests of maize, bean and pigeonpea and to identify indigenous methods for pest control. These information sources, together with a survey of the relevant literature (Ritchie *et al.*, 1997), and findings from the Stakeholder Workshop (Ritchie, 1996) and the earlier Soil Pests Project (1992, 1993) facilitated the selection of a range of IPM interventions for each of these major crops, for testing in on-farm experimental trials.

In the first crop season (1996/97), pest management strategies for the different crops were included within one on-farm experiment involving 64 farmers. The strategies for pigeonpea against yield losses due to *Fusarium* wilt, included the use of one of two varieties, and the use of one of two planting positions. In subsequent years (1997/98 and 1998/99) only varietal tolerance was investigated with respect to the pigeonpea intercrop since it was felt that the use of resistant cultivars was the only viable technology for management of *Fusarium udum*. The local variety and the wilt resistant variety ICP 9145 were used – the same as in the previous year. Two additional cultivars were included in the trial: the wilt resistant Kenyan landraces offered by ICRISAT's technology transfer specialist, i.e. ICEAP 00040 and ICEAP 00053. Along with ICEAP 00020 (not available in sufficient quantities for our trials), ICEAP 00040 and ICEAP 00053 are being promoted regionally by ICRISAT because of their high yield potential and large seed size. ICEAP 00040 is wilt resistant, whereas ICEAP 00053 is only regarded as wilt tolerant in Kenya. It was important to investigate the performance of these two varieties under smallholder management.

This paper present the findings from all three seasons of researcher-designed, farmer-managed on-farm trials of pest management strategies against *Fusarium* wilt in pigeonpea and suggests varieties that are suitable for farmers growing pigeonpeas intercropped with maize in Blantyre/Shire Highlands.

MATERIALS AND METHODS

In each of the three seasons, experimental trials were carried out in Matapwata and Chiradzulu EPAs in cropping systems where maize is intercropped with pigeonpea and bean planted in November–December. In 1996/97, a standard plot size, 10.8 x 10.8 m gross, 9 x 9 m net, was used. In the two subsequent seasons, the plot size was halved to 10.8 x 5.4 m gross.

In 1996/97, 64 farmers participated in the trial, 16 each with fields in Matapwata *dambo*, Matapwata upland, Chiradzulu *dambo* and Chiradzulu upland. Harvest data were recorded for one experimental plot and one farmer's plot on each farm. Plant deaths due to various causes were recorded for only the experimental (research) plot.

In the 1996/97 season, two methods of protecting pigeonpea plants against wilting due to *Fusarium udum* were investigated, i.e. planting position and the use of an appropriate resistant pigeonpea variety. The varieties included were the local variety and the wilt resistant variety ICP 9145. There were two planting positions, planting on the ridge top and planting on the ridge side. These treatment factors were included with several other treatment factors applied to the maize and bean intercrops. As a result, each farmer saw only a subset of the methods used and was unable to evaluate the different interventions included in the trial.

In view of these difficulties, the 1997/98 trial was simplified to include only one treatment factor with respect to the pigeonpea crop, i.e. the use of four different varieties. The varieties used were: ICP 9145, ICEAP 00053, ICEAP 00040 and a local variety. All four varieties were grown on each farm, 1 plot/variety, so that farmers could observe varietal differences. The trial also included banking as an intervention for the management of termite damage in maize, and seed dressing (Gaucho) for the maize crop to control whitegrub attack. The possible influence of these factors on pigeonpea yield responses was also of interest.

Thus for pigeonpeas, there were three treatment factors:

- banking: yes or no, except in Chiradzulu *dambo* where farmers usually bank their plots
- dressing maize seed with Gaucho: yes or no
- varietal tolerance: local, ICEAP 00053, ICEAP 00040 and ICP 9145.

A total of 61 farmers participated in the 1997/98 main intercrop trial, each farmer maintaining four research plots on one of his/her fields. The distribution of farmers across villages is shown in Table 1 according to the type of land (*dambo*/upland) that they farm.

In the 1998/99 season, a subset of the above farmers, i.e. a total of 40 farmers, was included in a follow-up trial aimed at investigating one management strategy for pigeonpea and one for bean. Both pest management strategies involved the use of suitable varieties, i.e. pigeonpea varieties believed to be resistant to *Fusarium* wilt and bean varieties believed to be resistant to attack by bean stem maggot.

The distribution of farmers across EPAs, villages and zones is shown in Table 2 below.

The experimental design used for the 1997/98 main intercrop trial is provided in a separate report (Abeyasekera, 1998). The general form of the design was that of a randomized block experiment for each treatment factor with farmers being regarded as blocks. Factorial combinations between treatment factors were incorporated to ensure that the relevant 2-factor interactions could be estimated.

Table 1. Distribution of farmers across villages and land types (1997/98)

	Chiradzulu		Matapwata		
Land type (zone)	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	11	6	8	5	30
Upland	5	12	7	7	31
Total	16	18	15	12	61

Table 2. Distribution of farmers across villages and land types (1998/99)

	Chiradzulu		Matapwata		
Land type (zone)	Chiwinja	Lidala	Kambuwa	Magomero	Total
Dambo	8	6	4	5	23
Upland	2	8	3	4	17
Total	10	14	7	9	40

Table 3. Adjusted means for major yield responses

Treatment factors	Usable seed weight (kg/ha)	Total pod weight (kg/ha)	No. plants with pods	Plant height (cm)	Stand count at harvest
Variety					
Local	61	146	56	157	68
ICP 9145	83	189	58	149	71
P	0.519	0.556	0.858	0.452	0.745
Planting position					
Top of ridge	66	171	58	157	69
Side of ridge	74	160	56	150	69
P	0.818	0.879	0.833	0.577	0.987
Residual df	48	48	49	41	50

The follow-up trial in 1998/99 was carried out on the same set of plots and had the same treatment structure as used in 1997/98 except for the absence of seed dressing on maize and with all plots banked according to farmers' usual practice.

RESULTS FROM THE 1996/97 SEASON

Pigeonpea harvests

Five yield response variates were considered for analysis, i.e. the usable seed weight (kg/ha), the total pod weight (kg/ha), the total number of plants with pods at harvest, plant height (cm) and stand count at harvest. The data were subjected to analysis of variance (ANOVA) procedures to investigate the effect of each of the two treatment factors on the yield responses, after allowing for variation between villages and zones.

In analysing the data, all five responses showed significant differences between zones and between villages. Seed weight and total pod weight alone gave, in addition, a village by zone interaction but there was insufficient evidence to indicate a variety difference. However, yields from ICP9145 were better than the local variety. For seed weight, there was a 36% increase, while for pod weight there was a 29% increase. The results for all five variates are summarized in Table 3.

Analysis of damage data during the season

The total number of plant deaths over the season by *Fusarium* wilt, as a proportion of the post-germination stand count, was modelled to study its variation across the two pigeonpea treatment factors and across land types, EPAs and villages. None of the latter effects gave significant differences. Of the treatment factors there was only a marginal effect due to planting position (P=0.069). The proportions killed under each level of the treatment factors are shown in Table 4. The increase in proportions killed under row planting compared to ridge planting was 3.3% with SE = 1.8.

Analysis of damage data recorded at harvest

In relation to plant damage at harvest time, four variates were measured:

- the number of termite-lodged plants in net plot
- the number of wilted plants in nett plot due to *Fusarium* wilt
- the number of whitegrubs in a random sample of 10 plants from the plot
- the number of nematode-affected plants in a random sample of 10 plants.

The first of the above variates had a non-zero recording for one plot only. There was no termite attack observed in the remaining plots. Data analysis was therefore unnecessary for this variate. Percentage of plots with damaged plants appear in Table 5. The percentages for *Fusarium* wilt and nematode attack were significantly different across the EPAs, but not across *dambo* and upland areas. There was also no evidence of varietal differences. Occurrence of whitegrubs at harvest was significantly higher (P=0.0018) when pigeonpea was planted on the ridge top (12.0%) than when it was side planted (51.6%).

Table 4. Mean percentage of plants per plot killed by *Fusarium* wilt and by all other causes

Factor	Termites (%)	Whitegrubs (%)	*Fusarium* wilt (%)	Bacterial wilt (%)
Local variety	1.21	0.00	6.76	0.08
Variety ICP 9145	0.22	0.17	5.14	0.13
Planted on ridge top	1.22	0.05	7.60	0.05
Planted on ridge side	0.21	0.12	4.30	0.16

Table 5. Percentage plots in each EPA, under each variety and under each level of planting position with one or more plants having *Fusarium* wilt/whitegrub/nematode attack

Factor		Fusarium wilt (%)	Whitegrub (%)	Nematode (%)
EPA	Chiradzulu (*n*=30)	43.3	20.0	10.0
	Matapwata (*n*=26)	85.2 (*n*=27)	50.0	46.2
	P for difference between the two percentages	<0.001	0.018	0.002
Variety	Local (*n*=30)	67.7 (*n*=31)	33.3	26.7
	ICP9145 (*n*=26)	57.7	34.6	26.9
	P for difference between the two percentages	ns	ns	ns
Planting position	Ridge top (*n*=25)	61.5 (*n*=26)	12.0	28.0
	Ridge side (*n*=31)	64.5	51.6	25.8
	P for difference between the two percentages	ns	0.0018	ns

Damage was low with respect to whitegrub numbers and presence of nematode galls in randomly selected plants. Therefore, further statistical modelling procedures were applied only to data on the number of plants affected by *Fusarium* wilt. However, this analysis did not demonstrate differences between varieties or between planting positions.

Conclusions from the 1996/97 main intercrop pigeonpea trial

(i) ICP 9145 had a marginally better yield performance than the local variety with respect to usable seed weight (kg/ha) and pod weight (kg/ha), but the differences were not significant. Compared to the local variety, ICP 9145 gave a 36% increase in seed weight and a 29% increase in pod weight.

(ii) Percentage of plant deaths (over the season, as defined on p. 182) by *Fusarium* wilt was around 5%. The estimated percentage for the local variety was 6.8% compared with 5.1% for ICP 9145. The difference between these two proportions was not statistically significant (P=0.368). The estimated percentage of plant deaths by *Fusarium* wilt was 7.6% for ridge-top planting and 4.3% for ridge-side planting. The difference in these two proportions was marginal with a P value of 0.069.

(iii) With respect to the percentage of the plots having one or more plants attacked by *Fusarium* wilt, whitegrubs or nematodes, no differences were observed between the local variety and ICP 9145. Whitegrub attack alone was found to be considerably lower when the planting was on the ridge top (at 12.0% incidence) as compared to planting on the ridge side (51.6% incidence).

RESULTS CONCERNING PIGEONPEA HARVESTS FROM THE 1997/98 AND 1998/99 SEASONS

Three yield responses were considered for comparing yield performance across the four pigeonpea varieties in each of the two seasons:

- usable seed weight (kg/ha) adjusted for the moisture content
- weight of 100 randomly selected seeds (g)
- number of seeds per pod as determined from seed in 20 randomly selected pods.

In the 1997/98 season alone, two additional treatment factors were also included in the trial, i.e. maize seed dressing and banking. Variation in yield parameters across these two factors was also of interest, as were the interactions amongst the three factors and their interactions with land type and EPA. Banking was generally always practised in Chiradzulu *dambo* areas, so the analysis involving banking was restricted to the remaining areas.

In all analyses involving data from 1997/98, neither seed dressing nor banking had any effect on pigeonpea yields. Therefore, these factors will not be considered further in this paper.

Usable seed weight (kg/ha)

Results from the 1997/98 season

ANOVA techniques applied to usable seed weight (kg/ha) showed that the variance homogeneity assumption was violated. The data were, therefore, transformed to logarithmic values and analysed. In this analysis, significant differences

Table 6. Pigeonpea variety performance on the basis of usable seed weight (kg/ha) (1997/98)

Variety	Seed weight means (log-scale)		Seed weight means (raw scale)		Overall variety means
	Dambo	Upland	*Dambo*	Upland	
Local	2.88	4.91	17.8	136.0	49.4
ICEAP 00053	3.47	4.60	32.0	99.8	59.1
ICEAP 00040	3.98	5.35	53.6	210.0	107.8
ICP 9145	4.18	5.08	65.6	160.6	101.5
SE (diff)	0.25	0.24			

Table 7. Usable seed weight across land types and EPAs (1997/98)

Land type	Seed weight (log-scale)		Seed weight (raw scale)	
	Chiradzulu	Matapwata	Chiradzulu	Matapwata
Dambo	4.04	3.05	56.6	21.2
Upland	5.71	3.39	301.6	29.7
Overall EPA means	4.95	3.20	140.9	24.6

were found between pigeonpea varieties with respect to the amount of usable seed weight (kg/ha) produced ($P<0.001$). EPA and land type differences were clearly significant ($P<0.001$) and there was also evidence of an EPA by land type interaction. There was some evidence that variety differences varied across land types shown by a significant variety by land type interaction ($P=0.030$). However, variety effects did not vary across EPAs ($P=0.417$).

The results are summarized in Tables 6 and 7 in terms of the log-transformed values as well as the results back-transformed to the original scale. Results of Table 6 clearly show that variety differences are largely due to ICEAP 00040 and ICP 9145 giving much higher yields than the local variety or ICEAP 00053, the differences on the log-scale being particularly evident in *dambo* areas. Further analyses showed strong evidence of a difference between these two groups (SE (diff) = 0.27) in farms cropped in *dambo* land ($P<0.001$), but in the upland areas, the differences (SE (diff) = 0.22) were not so strong ($P=0.014$). In the uplands, ICEAP 00053 performed worst. Its yields were significantly lower than yields for ICEAP 00040 ($P=0.003$) and ICP 9145 ($P=0.054$). However, yields of ICEAP 00053 were not significantly different to that of the local variety ($P=0.207$). There was insufficient evidence of a significant difference between ICP 9145 and ICEAP 00040. Results in Table 7 show that farms in Chiradzulu get significantly higher pigeonpea yields compared to farms in Matapwata EPA. The difference between EPAs is larger in the uplands than in the *dambo* areas.

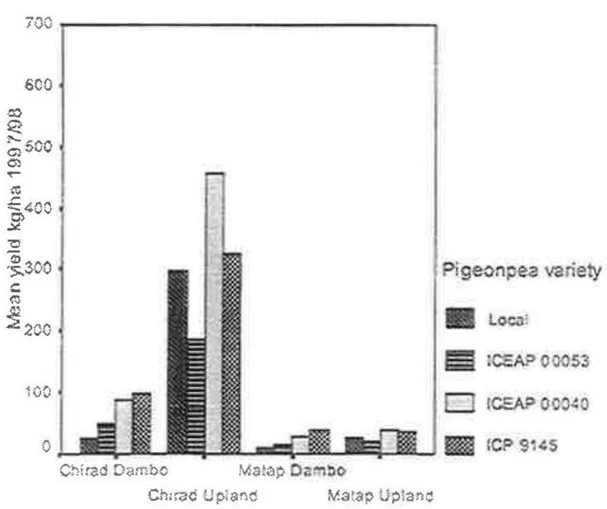

Figure 1. Usable seed weight (kg/ha) across locations and varieties (1997/98).

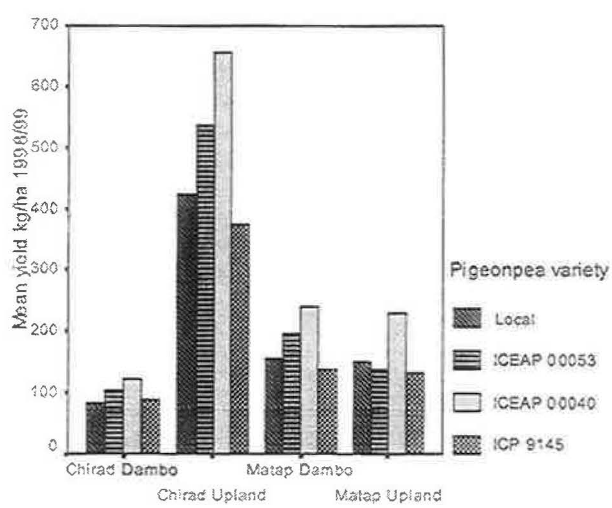

Figure 2. Usable seed weight (kg/ha) across locations and varieties (1998/99).

Table 8. Pigeonpea variety performance on the basis of usable seed weight (kg/ha) (1998/99)

Variety	Seed weight means (log-scale)		Seed weight means (raw scale)		Overall variety means
	Dambo	Upland	*Dambo*	Upland	
Local	4.60	5.86	99.7	349.7	171.7
ICEAP 00053	4.84	6.08	126.6	435.3	213.8
ICEAP 00040	5.01	6.29	149.8	541.3	263.5
ICP 9145	4.61	5.73	100.6	309.2	164.8
SE (diff)	0.15	0.15			

Table 9. Usable seed weight across land types and EPAs (1998/99)

Land type	Seed weight (log-scale)		Seed weight (raw scale)	
	Chiradzulu	Matapwata	Chiradzulu	Matapwata
Dambo	4.58	5.18	97.4	177.9
Upland	6.19	5.07	486.4	158.8
Overall EPA means	5.35	5.15	210.0	171.7

Results from the 1998/99 season

As in the previous season, there were clear differences between varieties (Table 8) and strong evidence of a land type by EPA interaction (Table 9). In this season, ICEAP 00053 performed much better than in the previous season but the mean yields under ICEAP 00053 were not significantly different to yields corresponding to the remaining varieties. Both the local variety and ICP 9145 were found to be significantly worse than ICEAP 00040. There was insufficient evidence of a difference between the two ICEAP varieties. Results of Table 9 show the poor performance of pigeonpea in Chiradzulu *dambo*. Highest yields were found in Chiradzulu upland areas.

Weight (g) of 100 seeds

Results from the 1997/98 season

Analysis of data concerning the weight of 100 randomly selected seeds, carried out on the raw scale, showed strong evidence of differences between varieties ($P<0.001$). There was insufficient evidence of a seed dressing or banking effect, nor of an EPA effect. However, there was possibly a marginal effect due to land type. The mean values for the weight of 100 seeds across varieties and land types appear in Table 10.

Results from the 1998/99 season

Data from the 1998/99 season gave 100-seed weights that were lower on average than those of the previous season, but again there were clear differences between the varieties ($P<0.001$). The results are shown in Table 11 and are seen to be consistent with results in 1997/98. Again the two ICEAP varieties give higher 100 seed mass compared to the local variety and variety ICP 9145 ($P<0.001$). There was no evidence of a difference between the two ICEAP varieties, nor of a difference between the local variety and ICP 9145.

Mean number of seeds per pod

Results from the 1997/98 season

Analysis of the mean number of seeds/pod (determined from the number of seeds in 20 pods) showed no evidence of EPA differences averaged across land types ($P=0.926$) or of land type differences averaged across EPAs ($P=0.557$). How-

Table 10. Mean weight (g) of 100 pigeonpea seeds (1997/98)

Land type	*Dambo*	Upland	Variety means
Local	26.9	23.8	25.1
ICEAP 00053	29.5	27.3	28.2
ICEAP 00040	28.4	26.2	27.2
ICP 9145	25.1	22.1	23.5
SE (diff)	1.4	1.2	1.2

Table 11. Mean weight (g) of 100 pigeonpea seeds (1998/99)

Land type	*Dambo*	Upland	Variety means
Local	18.0	19.4	18.7
ICEAP 00053	22.0	23.5	22.8
ICEAP 00040	22.3	23.7	23.0
ICP 9145	17.8	19.1	18.5
SE (diff)	1.01	1.02	1.02

Table 12. Mean number of seeds/pod across land types and varieties (1997/98)

Variety	*Dambo*	Upland	Overall variety means
Local	4.7	4.8	4.8
ICEAP 00053	4.3	4.2	4.2
ICEAP 00040	4.8	4.8	4.8
ICP 9145	5.2	4.4	4.8
SE (diff)	0.37	0.34	0.37

Table 13. Mean number of seeds/pod across land types and varieties (1998/99)

Variety	*Dambo*	Upland	Overall variety means
Local	4.9	5.1	5.0
ICEAP 00053	4.6	4.7	4.6
ICEAP 00040	5.1	5.2	5.2
ICP 9145	5.0	5.2	5.1
SE (diff)	0.19	0.16	0.16

ever, there was evidence of an EPA by land type interaction (P=0.009). This was due to mean numbers of seed per pod being higher in *dambo* than in upland within Chiradzulu EPA, but upland mean values being higher than *dambo* in Matapwata. The differences were less than 1 seed/pod and are, therefore, unlikely to be of practical importance.

There was some indication that varieties performed differently with respect to the mean number of seeds/pod (P=0.055), and that this difference varied across land types (P=0.068). Table 12 summarizes the results. The differences are due to variety ICEAP 00053 performing significantly worse than ICP 9145 (P=0.007) in *dambo* areas, and rather worse than the local variety in upland areas (P=0.062). But all varieties yield over 4 seeds/pod, so differences between them are small and have little practical implication.

Results from the 1998/99 season

Results in this season were comparable to those in the 1997/98 season. ICEAP 00053 gave fewer seeds per pod than the other three varieties which all yielded about 5 seeds/pod on average. The results are given in Table 13.

Damage during the season

Plot level incidence

Chi-squared analyses were carried out to investigate whether the observed numbers of plots affected or not by *Fusarium* wilt and other causes through the cropping season varied significantly across varieties. There was some evidence (P=0.042 and P=0.006 in the two seasons) that the deaths due to *Fusarium* differed across varieties (Tables 14 and 15).

Table 14. Number (and %) of plots with plant deaths from *Fusarium* wilt/stem rot and stem canker, by variety (1997/98)

Variety	No. plots with *Fusarium* deaths	% of plots with *Fusarium* deaths (n=61)	No. plots with stem/root rot deaths	% of plots with stem/root rot deaths (n=61)	No. plots with stem canker deaths	% of plots with stem canker deaths (n=61)
Local	58	95	14	23	27	44
ICEAP 00053	57	93	20	33	26	43
ICEAP 00040	50	82	20	33	25	41
ICP 9145	57	93	20	33	28	46
P	0.042		0.553		0.954	

Table 15. Number (and %) of plots with plant deaths from *Fusarium* wilt and from all causes, by variety (1998/99)

Variety	No. plots with *Fusarium* deaths	% of plots with *Fusarium* deaths (n=37)	No. plots with deaths by all diseases	% of plots with deaths by all diseases (n=37)
Local	30	81	34	92
ICEAP 00053	26	70	32	87
ICEAP 00040	18	49	25	68
ICP 9145	18	49	26	70
P	0.006		0.22	

Table 16. Model predictions of percentage of *Fusarium* affected plants across EPAs and land types (1997/98)

EPA	Land type		Overall EPA effect
	Dambo	Upland	
Chiradzulu	6.1	5.2	5.6
Matapwata	46.5	38.5	42.3

Table 17. Model predictions of percentage of *Fusarium* affected plants across varieties and land types (1997/98)

Variety	Land type		Overall variety effect
	Dambo	Upland	
Local	28.3	20.9	24.4
ICEAP 00053	27.6	23.2	25.3
ICEAP 00040	24.0	18.9	21.3
ICP 9145	18.8	17.4	18.1

In 1997/98, this appears to be due to ICEAP 00040 giving a slightly lower rate of incidence than the other three varieties. In the 1998/99 season, both ICEAP 00040 and ICP 9145 give lower plot incidence.

Incidence by stem/root rot and stem canker did not vary significantly across the varieties in the 1997/98 season. In the next crop season, there was an outbreak of *Sclerotium rolfsii* which caused difficulties in accurately identifying the different diseases. Data were, therefore, analysed according to the total of all plant deaths by diseases. Although results for deaths by *Fusarium* are given in Table 15 (and subsequently in Table 17), these results must be viewed with some caution in view of the uncertainty in diseases being identified correctly.

Results of modelling percentages of plant deaths through the season

Generalized linear modelling procedures with a binomial error structure were used to investigate whether the number of plants affected by *Fusarium* wilt, considered as a percentage of the initial germination stand count, varied significantly across the treatment factors.

In the 1997/98 season, analysis of *Fusarium* deaths showed strong evidence of an EPA effect and a land type effect ($P<0.001$) and some evidence of a land type by EPA interaction. There were clear differences across varieties and evidence of a land type by variety interaction ($P<0.001$ and $P=0.007$ respectively). The results are shown in Tables 16 and 17.

Clearly *Fusarium* wilt is a much more serious problem in Matapwata than it is in Chiradzulu. Amongst the varieties, both the local variety and ICEAP 00053 show higher percentages of plant deaths than the other two varieties. The differences are significant, but not large enough to be of practical importance.

In the 1998/99 season, analysis of all plant deaths by diseases showed strong evidence of differences across variety differences ($P<0.001$). There was also evidence that these differences varied across land types and EPAs ($P=0.004$ and $P<0.001$ respectively). Results are presented in Table 18 for each land type within each EPA. ICEAP 00053 shows least resistance to diseases in Matapwata. In Chiradzulu, both the local variety and ICEAP 00053 perform less favourably than ICEAP 00040 and ICP 9145.

Plant deaths recorded as deaths by *Fusarium* also demonstrate that ICEAP 00040 and ICP 9145 are more resistant to *Fusarium* than ICEAP 00053 ($P<0.001$). The differences between ICEAP 00040 and ICP 9145 are not significant. In Chiradzulu, there is little difference between the local variety and ICEAP 00053, but in Matapwata, they are significantly different ($P=0.002$).

Relationship between yield and damage data (1997/98 season)

Damage data collected over the growing period in the 1997/98 season were also investigated to see if usable seed weight was affected by pest and disease damage occurrences. The damage variables investigated were deaths by *Fusarium* wilt, stem/root rot, stem canker, termites, nematodes and whitegrubs. The relationship of yield with the total mortality was also considered.

Of all the damage data studied, evidence of an influence on usable seed weight was found only with respect to the mean numbers of deaths by *Fusarium* wilt ($P=0.003$) and total mortality ($P<0.001$). The latter was determined as the difference between plant stand at harvest time and the initial germination stand count. These effects did not vary significantly across the pigeonpea varieties included in the trial. Plots of mean seed weight against number of deaths by *Fusarium* are shown in Figure 3.

Table 18. Percentage plant deaths by all diseases (1998/99)

Variety	Chiradzulu		Matapwata		Overall variety means
	Dambo	Upland	*Dambo*	Upland	
Local	9.7	8.8	12.5	12.5	10.5
ICEAP 00053	8.8	9.2	19.2	21.8	13.3
ICEAP 00040	4.9	3.4	8.1	6.3	5.4
ICP 9145	8.7	5.3	8.2	5.5	7.1

Table 19. Percentage plant deaths by *Fusarium* wilt (1998/99)

Variety	Chiradzulu *Dambo*	Chiradzulu Upland	Matapwata *Dambo*	Matapwata Upland	Overall variety means
Local	7.1	9.2	2.9	3.3	6.1
ICEAP 00053	6.4	8.2	8.4	9.2	7.9
ICEAP 00040	2.5	3.0	3.0	3.3	2.9
ICP 9145	3.3	4.1	1.9	2.2	3.1

CONCLUSIONS

Yields were consistently lower in Matapwata (25 kg/ha and 170 kg/ha in 1997/98 and 1998/99, respectively) than Chiradzulu upland (302 kg/ha and 486 kg/ha in the two seasons). *Dambo* fields in Chiradzulu are seasonally waterlogged with cracking clay soils. Here pigeonpea yields are even lower than in Matapwata (<100 kg/ha).

Fusarium wilt incidence in all years was much higher in Matapwata than in Chiradzulu. Disease is likely to be a significant factor in the observed poor performance of pigeonpea generally in the wetter colder conditions of Matapwata. There is some indication of a link between deaths due to *Fusarium* and eventual yields.

ICP 9145 is shown to be a reliable yielding pigeonpea with good wilt resistance. However, seed size, although variable, is generally poor compared with the ICEAP varieties, being consistently slightly smaller than even the local variety.

ICEAP 00053 showed great variation in yield between years. Yields were intermediate between ICEAP 00040 and ICP 9145 in 1998/99, whereas in 1997/98 it yielded little more than the local variety. The average number of seeds per pod is consistently lower than the other three varieties but the seed is as big as ICEAP 00040. The main disadvantage of this variety lies in its apparent susceptibility to *Fusarium* which is comparable with the performance of the local variety.

ICEAP 00040 is consistently the best performer in 1997/98 and 1998/99 in terms of overall yields, deaths due to diseases (in general) and deaths due to *Fusarium*. The seed size is larger than any of the other varieties except ICEAP 00053, while the number of seeds per pod approaches levels found in ICP 9145.

From these results it can unequivocally be recommended that ICEAP 00040 is suitable for release in Blantyre/Shire Highlands and will deliver significant benefits to smallholders. Farmer acceptability is also high on taste, size, yield, firewood and marketability (Mwale, 1998; Sutherland, 1998). Acceptance by Dhal Millers Association Limited is also high due to its large pale seeds and easily removed seed coat. The processors would like to see ICEAP 00040 replace ICP 9145 as soon as possible (Likoswe, personal communication).

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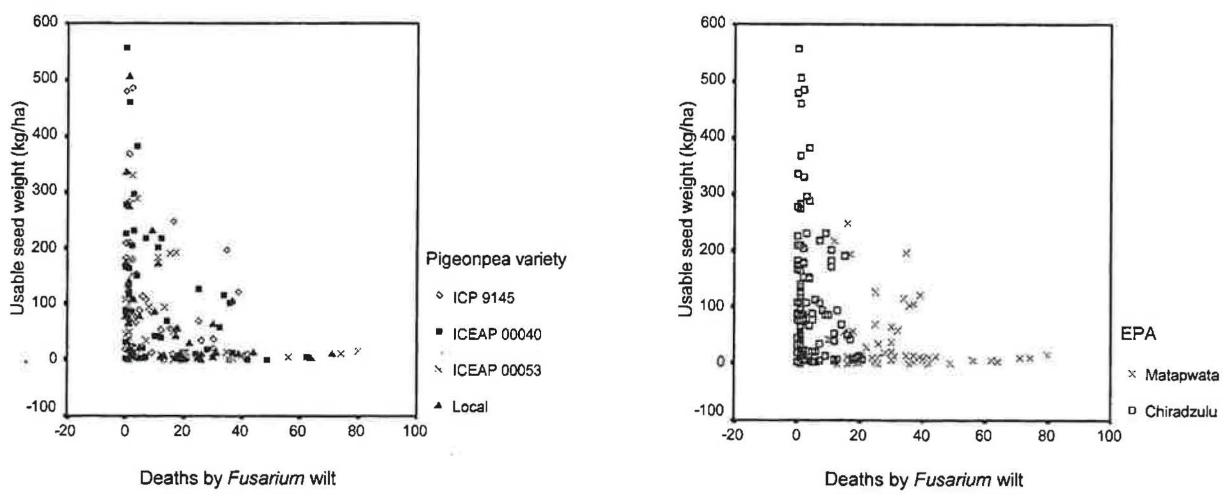

Figure 3. Usable seed weight against mortality by Fusarium *wilt.*

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DISCUSSION

A. A. Chirembo. Was it not known beforehand that the four varieties under study were behaving differently from the time you obtained them from the breeder? If that was the case, why then work with four varieties rather than with one or two which were recommended by the breeder?

S. A. Two were varieties already used by farmers. The other two had been tested in on-station trials and were found to perform well. It was important to see whether the latter two would offer an advantage when tested under smallholder management.

V. Kabambe. Your season by variety interaction is interesting. It tends to suggest one season's results may produce false conclusions. How did you advise the project considering that many treatments were dropped after a year?

S. A. I agree with your point. It is difficult to judge whether or not a treatment should be dropped because of poor performance in a single year. If not for resource implications, we would ideally like to try most treatments in at least three seasons before coming to firm conclusions.

5. Weed Management in Smallholder Intercropped Maize

KEYNOTE ADDRESS
The 6-week window: farmers' decision-making for weeding

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ABSTRACT

Researchers recommend that maize be kept free of weeds for the first 6 weeks after emergence. Weeding decisions include the choice of technique, the allocation of labour between household members, and the allocation of household labour between weeding and off-farm employment. Farmers used different weeding techniques for fields with termites or where weeding was delayed by continuous rains. Households where fields were separately owned exchanged labour for weeding. Adolescents rarely helped with weeding. Women in fragile marriages weeded late if their husbands did not participate. Late second weeding was more frequent among households that were headed by women, had higher maize deficits and could not afford to hire labour. The main explanation for late weeding was not shortage of household labour, but lack of effective demand for hired labour. Until poorer households have greater cash incomes, high crop losses from weeds will remain a permanent feature of smallholder agriculture in the Blantyre/Shire Highlands.

INTRODUCTION

Weeds are arguably the only field pest of food crops in southern Malawi of general economic significance. Other pests and diseases periodically inflict severe losses, but average levels of damage are low. By contrast, crop losses from weeds are consistent, widespread and severe if not controlled. Farmers, therefore, invest heavily in labour for weed management. If we knew more about farmer decision-making for weeding, we would know more about how farmers allocate labour. If we knew more about how farmers allocate labour, we would know more about the farm household and the constraints facing smallholder agriculture.

Researchers recommend that farmers keep maize free of weeds for the first 6 weeks after emergence (MOALD, 1994). Farmers' weeding decisions during the '6-week window' cannot be treated in isolation, however. The increase in labour demand for weeding coincides with factors that reduce labour supply. Most smallholder households run out of maize at this time and must depend on the market for maize purchases. Cash to buy maize is often obtained by selling labour, reducing labour available for weeding. Moreover, morbidity is higher during the wet season. This reduces the labour time for crop production directly and indirectly through the need to care for sick children and relatives.

The general objective of this keynote paper is to provide the context for the technical presentations that follow. We begin by looking more closely at the types of decisions that farmers make in allocating labour for weeding. Next we examine the evidence for how these types of decisions are made. Finally, we draw some general conclusions about farmer decision-making for weeding and the light it sheds on wider aspects of the farming system.

THEORY: TWO MODELS OF DECISION-MAKING

Decision matrix

A decision may be defined as a choice between alternatives based on imperfect information.

Information is imperfect because farmers cannot predict the final yield from a particular plot. They cannot predict weather, attack by termites, the sickness of family members, or funerals of neighbours and relatives.

The farmers' choice of alternatives in decisions about labour allocation for weeding is shown in the form of a 3 x 3 matrix (Figure 1). The matrix allows for 27 different decisions, indicating the complexity of farmers' weeding decisions.

When to weed? This decision will depend on field-level variables (weediness, rainfall) as well as the stock of household labour available for weeding, and its alternative uses.

Who will weed? At the field level this decision might depend on which member of the household has the right to cultivate a particular field. It may also depend on de-

Decision	Weeding		Off-farm enterprises
	Field level	Household level	
When?			
Who?			
What type?			

Figure 1. Decision-matrix for weeding.

cisions made at the household level. If members of the household have particular skills in off-farm enterprises, for example, they might decide to do less weeding. Households may also decide to substitute hired labour for family labour.

What type of weeding? This may depend on agronomic field-level variables. Some weeding techniques, however, also economize on labour. If weeding has been delayed by sickness, or by the need to work off-farm, the household may choose a less labour-intensive form of weeding.

The matrix does not include a decision on *whether to weed* because farmers are well aware of the need for weeding. Most fields receive at least one weeding. If fields are not weeded twice it is usually because farmers expect low yields due to continuous rainfall or lack of fertilizer (Orr and Koloko, 1998).

A household model

Figure 2 shows a simplified economic model of weeding decisions. The four quadrats show the interactions between (i) household labour supply for weeding, (ii) timeliness of weeding, (iii) demand for hired labour for weeding, and (iv) household demand for maize purchases.

Quadrats 1 and 2: household labour supply for weeding, and timeliness of weeding

With labour supply curve S_1, available labour is maximized and units of labour supplied are at $O - L_3$. At level $O - L_3$, timeliness of weeding is at T_3, and 100% of the area planted to maize can be weeded twice within 6 weeks of emergence.

Sickness may reduce the household labour available for weeding. With a lower labour supply curve (S_2), the units of labour supplied fall to $O - L_2$. At level $O - L_2$, timeliness drops to T_2 and only 50% of the area planted to maize can be weeded twice within 6 weeks of emergence.

Quadrats 3 and 4: household demand for purchased maize, the supply of household labour for ganyu, *and the demand for hired labour*

The line *OD* shows household demand for maize purchases, and the line *OG* the supply of household labour for *ganyu* to earn cash to buy maize. When household demand for maize is at D_3, the cash requirement to purchase maize can be met with $O - G_3$ units of *ganyu* labour. This level of *ganyu* does not significantly reduce the supply of household labour for weeding, which remains at L_3. Consequently, the demand for hired labour (*H*) remains at zero (H_1). Timeliness remains at T_3, and 100% of the area planted to maize can be weeded twice within 6 weeks of emergence.

As household demand for purchased maize rises to D_1, the units of *ganyu* required to buy maize rises to G_1. This reduces the supply of household labour available for weeding to L_1 units. With this level of labour for weeding, timeliness drops to T_1, and less than 50% of the area planted to maize can be weeded twice within 6 weeks of emergence. To compensate, farmers hire labour. With household labour supply at L_1, households must hire H_3 units of labour to maintain timeliness at T_3, and ensure that 100% of maize is weeded within 6 weeks of emergence.

The model suggests a number of hypotheses about labour allocation for weeding:

- households where labour supply is lowered by the absence of adults or illness will weed later;
- households with higher maize deficits will allocate more labour to off-farm employment;
- households which allocate more labour to off-farm employment will weed later;
- households that allocate household labour to off-farm employment will not weed later provided that they can hire labour for weeding.

DATA AND METHODS

The data in this paper derive from three sources.

A panel survey of 109 households at FSIPM research sites in 1998/99 that collected data on the timeliness of weeding. Information on weeding was collected from the same households in a baseline survey in 1996/97 (Orr *et al.*, 1997) and a panel survey in 1997/98 (Orr and Koloko, 1998).

A study in the 1997/98 crop season which explored decision criteria for weeding at the field level. This was based on a small sample of 30 households at FSIPM research sites in the Blantyre/Shire Highlands (Orr and Koloko, 1998).

Case studies of 15 households in the 1998/99 crop season of labour allocation for weeding. To ensure that the households were representative, three households were selected from each of the five household types previously identified by cluster analysis (Orr and Jere, 1999).

Weeding decisions at the field level were analysed using hierarchical decision-trees (Gladwin, 1989). The decision criteria for the trees were elicited from key informants. These criteria were then ordered in sequence to form a tree. The decision-tree was validated by testing it with a separate sample of 30 randomly selected households from the same research sites. Since weeding

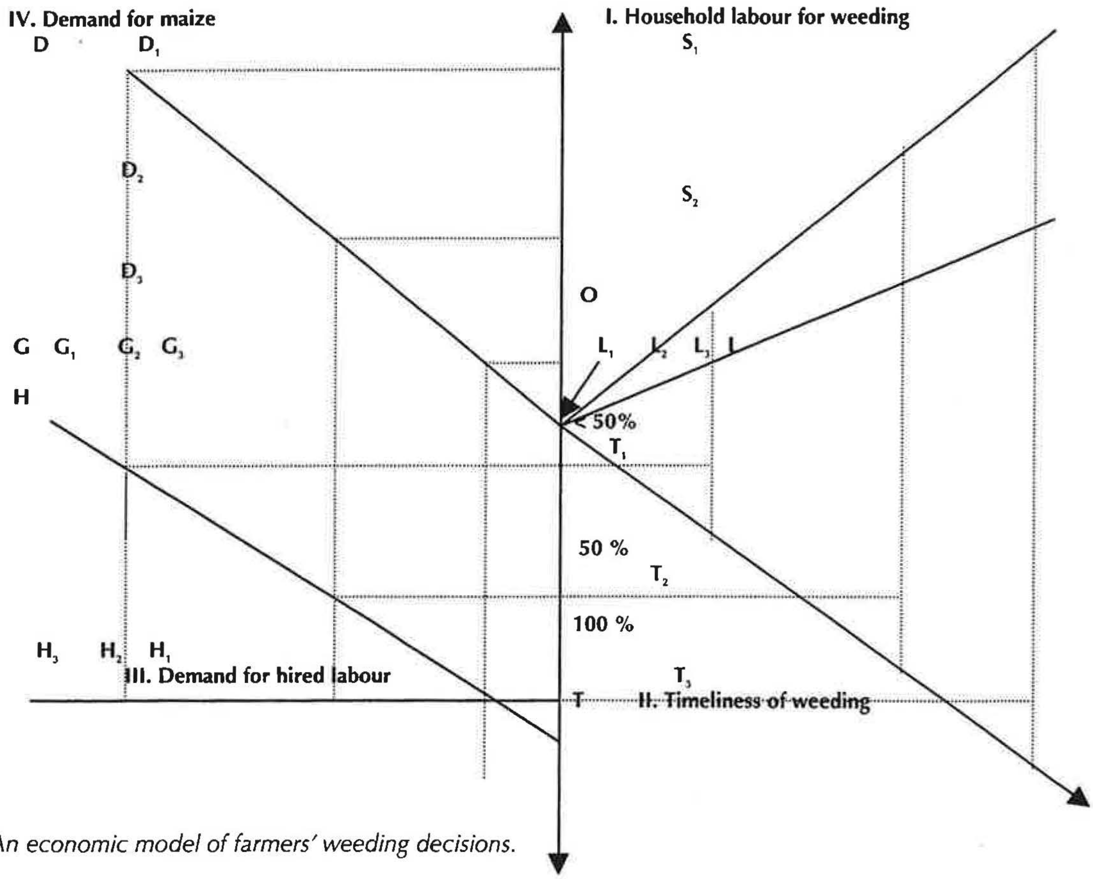


Figure 2. An economic model of farmers' weeding decisions.

practices may differ between fields, the answers for each decision criterion were determined separately for each field cultivated by the household.

Weeding decisions at the household level were analysed using quantitative data from the 1998/99 panel survey and from qualitative case studies. Although the circumstances of the households in the case studies varied widely, some fruitful generalizations emerged.

Table 1. Weeding techniques, FSIPM survey sites, 1997/98 season

Weeding technique	Fields (no.)	%	Area (ha)	%
First weeding				
Kupalira (fully)	51	89.5	18.0	86.3
Kupalira (partly)	4	7.0	2.5	11.9
Kusenda/kuwojekera	1	1.8	0.1	0.3
Not weeded	1	1.8	0.3	1.5
Second weeding				
Kubandira (fully)	30	52.6	10.9	51.9
Kubandira (partly)	7	12.3	12.3	19.9
Kubandira + *kukwezera*	5	8.8	2.1	8.1
Kukwezera	4	7.0	0.9	4.5
Kuwojekera	1	1.8	0.2	0.7
Not weeded	10	17.5	3.1	14.8
Total	57	100.0	20.9	100.0

Source: Orr and Koloko (1998).
n=57 fields.

RESULTS AND DISCUSSION

What type of weeding?

In addition to *kupalira* (used for first weeding) and *kubandira* (used for second weeding) farmers specified five additional weeding practices (Figure 3).

Of the 56 fields in the sample that received a first weeding, all but one were weeded using *kupalira* (Table 1). The remaining field was weeded using a technique known as *kusenda* or *kuwojekera*. Weeding is faster with *kusenda* than with *kupalira*, since the weeds are scraped from only one side of the furrow. Consequently, *kusenda* is often used when farmers are in a hurry or short of labour. In years of continuous rainfall, for example, farmers delay first weeding in order to avoid re-germination of weeds. To make up for lost time, they then use *kusenda* for first weeding rather than *kupalira*. Of the farmers in the sample, 43% reported using *kusenda* or *kuwojekera* at some point in their experience of weeding.

Of the 47 fields in the sample that received a second weeding, 37 (79%) were banked (*kubandira*) (Table 1). Of the remaining 10 fields, nine were weeded using *kukwezera*, and one was weeded using *kuwojekera*. *Kukwezera* is used

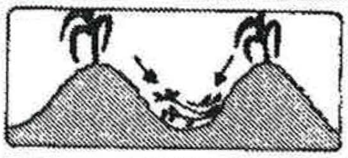
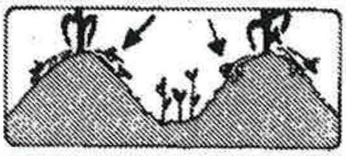
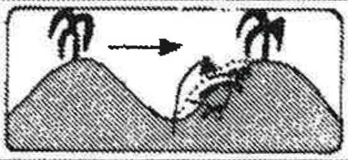
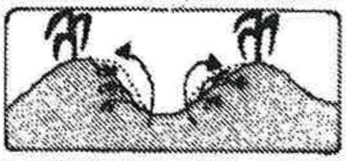
No.	Technique	Description	
1	*Kupalira*		Weeding by hoeing the sides of two ridges and laying weeds in the intervening furrow to dry them out
2	*Kuzulira* (*dambo*)		Hand weeding tall weeds, then scraping smaller weeds from sides of the ridge with a hoe and laying both on top of the ridge leaving weeds in furrow untouched
3	*Kuzulira* (hillslope)		Hand weeding tall weeds and laying them in the furrow or in a heap before starting *kupalira*
4	*Kusenda* or *Kuwojekera*		Weeding by hoeing weeds from the side of one ridge, downwards from the maize planting station, moving them to the side of the next ridge and burying the weeds
5	*Kukwazira* or *Kupala*		Weeding by using a hoe to scrape the weeds from the side of the ridge without moving the soil and leaving the weeds to dry
6	*Kukwezera*		Weeding by using the hoe to scrape weeds from one side of the ridge upwards towards the planting station, without burying the weeds
7	*Kubandira*		Banking or using the hoe to move soil from the furrow to build up the sides of the two ridges and support the maize plant, burying the weeds

Figure 3. Farmers' weed management practices, Blantyre/Shire Highlands, Southern Malawi. Source: Kadale Consultants.

where farmers fear damage from termites. Weeds are scraped upwards from the furrow on to the ridge but, unlike *kubandira*, they are not buried close to the planting station. While this technique may encourage lodging, farmers are evidently willing to take this risk. Termite damage varies considerably between seasons. When asked if they had ever used *kukwezera* against termites, 13 farmers (43% of the sample) replied 'yes'. Similar cultural practices against termites have been reported from Thucila (Shaxson *et al.*, 1993) and Machinga (Logan *et al.*, 1993).

The wide range of weeding techniques highlights the sophistication of farmer practices in hoe agriculture where techniques are carefully tuned to soil type, pests and labour availability. This is reflected in a rich farming vocabulary. The English verb 'to hoe' has no fewer than 36 equivalents in Chichewa (Guerin, 1985). A similar sophistication is also evident in farmers' cultural practices for land preparation (Orr *et al.*, 1998).

Who weeds?

Table 2 outlines the case study findings regarding the participation in weeding by different members of the household. The results show only the range of decision-making processes observed, however, and are not a complete typology. Three case studies presented in Box 1 focus on key variables that determine the supply of household labour.

Table 2. How households make decisions about who weeds

Household member	Degree of autonomy	Who weeds?
Male head of household	High	Decisions normally taken jointly with wife. Division of labour evident in *dimba* households, where women may be responsible for weeding maize. In fragile marriages, the husband may be absent for extended periods. Wives do *ganyu* or *geni* to earn cash to hire labour to help them complete weeding.
Female head of household	Low	In households where there are shared cultivation rights, labour is pooled and rotated from field to field (*chipere ganyu*). Sometimes there is a fixed schedule to ensure reciprocity. Members usually defer to the oldest member of the household in deciding the schedule for rotation of labour. Husband–wife teams do not participate in *chipere ganyu*.
	Low	Households without shared cultivation rights may exchange labour (*chipere ganyu*) with similarly placed households. This is reported to be less common than previously, however. If not, they will usually hire labour for weeding.
Adult female	High	If unmarried they will participate in *chipere ganyu* with other household members. If married, but still living with mother and sisters in a joint household, will weed her own field along with her husband.
Adult male	High	Will weed his wife's field and may weed the fields of other household members on a *ganyu* basis.
Adolescent, 18+	High	Adolescents are given the choice of whether or not to participate in weeding. No sanctions are taken against non-participants. They do not usually weed with the household in the afternoons. Those who participate in weeding *ganyu* may keep their earnings.
Child, 16–18	Moderate	Have usually 'graduated' from 'apprentice' fields and assist adult members of the household. May do *ganyu* weeding in the afternoons.
Child, 7–15	Low	Children (7–15) are assigned 'apprentice' fields to weed. They are allowed to keep the green maize from these fields. Older children who work as *ganyu* may keep their earnings.

'Ownership' of fields within the household

In households where members have separate cultivation rights, *nkokwes* (granaries) are individually owned, but maize is shared with other members of the household on a rotational basis.

Thus, household members have a common interest in timely weeding to ensure food security. Household labour is rotated between fields until weeding is complete on each field. Exchange labour of this type is known as *chipere ganyu*. Work is only classed as *chipere ganyu* if (i) the participants have their own fields and (ii) no payment in cash or kind is involved. Communal forms of labour (*thandize* or *chijawo*) where payment is made in sweet beer are no longer used for weeding at the FSIPM research sites.

Household structure

Adolescent males (18+) decide independently whether or not to participate in weeding and were not a dependable source of labour. By contrast, younger children (7–15) contribute to the household labour supply by weeding fields or parts of a field on an 'apprentice' basis.

Marriage relationships

Women in 'fragile marriages' are vulnerable to labour shortages at weeding if their husbands decide not to participate.

When to weed?

To test hypotheses about reasons for late weeding, households were divided into terciles based on the proportion of maize that had received a second weeding within 6 weeks of planting (Table 3).

Timeliness

Although there was no difference in the area under cultivation between terciles, they differed significantly in the timeliness of second weeding. Among households in the first tercile none of the area planted to maize had been banked within 6 weeks of emergence. The proportion among the second and third terciles was 61% and 100%, respectively.

Labour supply for weeding

A higher share of households in the first tercile (45%) was headed by women. However, there was no significant difference in the stock of labour available for second weeding. Participation rates for banking were generally lower for adult males than for adult females. The lowest participation rate for adult males was found in the first tercile (67%) and the highest in the third tercile (79%). This suggests that male participation was an important factor in timely second weeding. Days lost to illness were also higher in the first and second terciles, further reducing the household labour supply in these groups. Thus, the hypothesis that households

Box 1. How do households decide who weeds where, and when?

Limited matriarchy: Mai M.

Mai M. (49) lives with her mother Mai W. (67), her unmarried daughter E., and her brother W. (30) in Lidala village, Mombezi Extension Planning Area (EPA). There are no children. The household cultivates about 1.6 ha and is self-sufficient in maize despite using no fertilizer. The fields belong separately to individual members of the household, with Mai M. cultivating three, and the other adults one field each. W. also has responsibility for weeding his wife's field in Zomba. Although Mai M. is the titular head of the household, authority over labour allocation rests with her mother Mai W. Labour for weeding is rotated between fields. The four adults work on one field for 2 days before shifting to another field. During first weeding, however, the three women did not help W. because his wife was present, she was not helping them, and they felt two adults was sufficient for that field. Before W. had finished first weeding, however, his wife departed for home with a sick child. The others did not help him finish first weeding because they felt it would encourage his wife to be lazy. He was forced to bank the field without weeding first (*kuwojekera*). W. shares his labour freely in the morning, but any work he does on their fields during the afternoon is paid as *ganyu*. Should he choose to work on his own field in the morning, he is expected to help on theirs in the afternoon. As the only male in the household, he feels he has to help at least once a day. Despite a large adult labour force, Mai M. is still forced to hire *ganyu* to complete weeding in time. E. also hired *ganyu* for first weeding, paid from the sale of her own maize.

Autonomy and apprenticeship: Mai M. and Mai S.

Mai M. (48) lives in Magomero village, Matapwata EPA, and has two sons (E., 25, and L., 23) and one married daughter children (B., 22). A niece, S. (13) also lives with the household since her mother died last year. Her husband, Bambo M., has another wife and and rarely participates in fieldwork. The household cultivates four fields of 1 ha and ran out of maize in November. In theory, her two sons were available for weeding from the start of the season. However, for most of the period L. was absent in town. A small portion of one garden assigned to L. for weeding had to be weeded by E., who was present for about 6 weeks after planting but then also left for town. Consequently, the bulk of first and second weeding has fallen on Mai M. and S. L. now has a job hawking towels and women's headscarves while E. wants to be in town to be available for job interviews. Mai M. is happy that they have become self-supporting

Mai S. (36) and her four children (4, 7, 10 and 15) live in Lidala village, Mombezi EPA. Married for 8 years, her husband abandoned the family about 5 years ago. Mai S. lives with her mother Mai H. (50) and the two women share resources. The household ran out of maize in October, 5 months before the next harvest. Mai S. cultivates two fields of maize and one of burley tobacco. Mai H. cultivates one field and assists Mai S. with burley but not maize cultivation. A fourth field is reserved for Mai S.'s two oldest children, who also assist on some pieces of her mother's field. Mai S. assigned a field to them to develop a sense of responsibility. Although Mai S. made the ridges and helped apply the fertilizer, weeding and banking are left to the children. The childrens' field is stony and infertile. Mai S.'s son L. (15) did *kuwerenga ganyu* to earn MK10 of *ufa* after the household had not eaten *nsima* for 2 days.

A disaffection: Bambo and Mai C.

The C.'s are a young couple living in Kambuwa village, Matapwata EPA who have been married 6 years and have two small children (4 and 2). The family cultivate only 0.3 ha of maize, and ran out of food in October. Tension between husband and wife was very evident on the rare occasions we interviewed them together. During the 6 weeks after planting maize, Bambo C. (29) was absent for extended periods, leaving his wife to weed and bank their two gardens alone. He reported that he had been helping his widowed sister with her weeding and his mother with banking their fields in Mangazi village about 10 km away. In all, he was absent for about 25 days. All he had to show for working 7 days for his mother was 5 kg of urea. From his evasive answers and his wife's complaints, it appears that Bambo C. had in fact been working as *ganyu* but was unwilling to reveal this to his wife or to share much of the money he had earned. His sole contribution appears to have been MK100 which he earned as *ganyu* weeding his brother-in-laws' field. During his absence, Mai C. used this as working capital to buy and resell tomatoes in order to support herself and the children. Finally, she complained to his parents. As a result, Bambo C. agreed to provide MK30 for *ganyu* to assist his wife finish banking and to work at home on alternate days.

Another example is provided by 'the tale of the missing hoe'. K., the daughter of Mai C., quarrelled with her husband James Y. He departed angrily for his home village, taking with him the hoes that they had been using to weed their field. This meant that in his absence K. was unable to continue weeding. He remained absent between 23 December and 8 January, during which time their field stayed unweeded.

Table 3. Socio-economic factors determining timeliness of weeding, 1998/98 season, FSIPM sites, Blantyre/Shire Highlands RDP

No.	Variable	Tercile 1 (*n*=36)	Tercile 2 (*n*=36)	Tercile 3 (*n*=37)	All households (*n*=109)	*P*
1	Area cultivated (ha)	0.76	0.76	0.89	0.80	<0.526
2	Area banked within 6 weeks of planting (%)	0	61	100	53	<0.000
3	Area banked within 8 weeks of planting (%)	60	70	100	770	<0.000
4	Female-headed households (%)	45	27	28	55	<0.013
5	Household labour supply (unweighted)					
	Labour used for banking:					
	adult males	1.14	1.06	1.27	1.16	<0.667
	adult females	1.47	1.42	1.51	1.47	<0.865
	adolescents	0.33	0.58	0.27	0.39	<0.199
	children	0.11	0.08	0.08	0.09	<0.888
	Participation rate for banking (%):					
	adult male	67	70	79	73	<0.453
	adult female	94	94	88	92	<0.481
	adolescents	12	31	13	18	<0.215
	children	9	5	5	6	<0.575
6	Days lost to sickness:					
	adult males	1.9	1.9	1.3	1.7	<0.761
	adult females	7.1	8.4	2.7	6.1	<0.089
7	Months household bought maize in 1997/98 (no.)	4.4	5.4	2.9	4.2	<0.001
8	Days worked as *ganyu* (no.):					
	adult males	5.9	9.2	5.9	7.0	<0.068
	adult females	7.9	6.9	9.3	8.1	<0.871
9	Area banked with hired labour (ha)	0	0.05	0.30	0.12	<0.000
	Expenditure on hired labour (MK)	0	36	162	67	<0.000
10	Households buying fertilizer (%)	72	86	92	83	<0.217
	Total expenditure on fertilizer (MK)	600	882	1566	1013	<0.007
11	Sources of cash for fertilizer in 1998/99:					
	crop and livestock sales	7	8	7	22	<0.823
	off-farm income	3	15	13	31	<0.011
	transfers	4	2	6	12	<0.381
	credit	6	7	7	20	<0.969

Source: FSIPM panel survey, 1998/99.

with reduced labour supply will weed later is accepted.

Maize deficits

Households in the third tercile had significantly lower maize deficits in 1997/98. On average, they bought maize for 2 months less than households in the other two terciles.

Off-farm employment

Although employment in *ganyu* differed between men and women in the three groups, no significant difference was found in the total days of *ganyu* labour worked by the household. Thus, the hypothesis that households with higher maize deficits will do *ganyu* rather than weed was rejected. One explanation for widespread participation in *ganyu* among the groups is that most households have run out of maize when weeding begins in December.

Hired labour

A highly significant difference was found in the use of hired labour for banking. During the 6-week window, households in the first tercile relied solely on family labour for banking. By contrast, households in the third tercile used hired labour extensively. The area banked with hired labour in this tercile was 0.30 ha, or almost 40% of the area cultivated. The average cost was 162MK/household.

Liquidity

Generally, households in the third tercile had greater cash reserves with which to hire labour and buy fertilizer. Households in this tercile spent MK1566 on fertilizer compared to just MK600 among households in the first tercile. Higher liquidity appears to be related to off-farm income. This was the major source of cash for fertilizer purchases among households in the second and third terciles.

Summarized, the results show that:

- the link between late weeding and household labour supply exists but is fairly weak;
- households that weed late have higher maize deficits, but they do the same amount of *ganyu* during the 6-week window as other households;
- households that weed later use less hired labour; households that weed on time have generated cash to hire labour through off-farm enterprises;
- late weeding, therefore, is not so much the result of labour shortage as of lack of *effective demand* for hired labour. The obvious solution is to get cash into the hands of households that weed late. But how? And what prevents these households taking fuller advantage of existing market opportunities?

CONCLUSIONS

Weeds are an "unfashionable pest" (Lipton and Longhurst, 1989). With the exception of *Striga*, they raise no intriguing questions about farmer knowledge. Weeds offer little scope for elegant solutions like varietal resistance or biological control. The most IPM effective strategy – manual weeding – is limited by seasonal labour shortages. Weeds remain important, however, because of their economic significance as a pest and because the analysis of farmers' decision-making for weeding captures, in microcosm, several important features of the smallholder farming system.

The sophistication that farmers bring to this mundane task reminds us of how finely adapted farmers' cultural practices are to a farming system characterized by erratic rainfall, intercropping, pest build-up, and a seasonal labour bottleneck during the 6-week window. Variations in cultural practices are often so subtle that they escape the notice of researchers. Appreciating these subtleties, however, can teach us much about farmer decision-making.

Weeding decisions are complex. On top of the variation produced by the physical environment are superimposed additional layers of complexity that stem from variation in the allocation of labour between different household members, and variation in the allocation of labour to weeding or off-farm enterprises. Modelling this complexity is a challenging task. A decision-tree for second weeding involved 24 separate decision criteria (Orr and Koloko, 1998).

The complexity of farmer decision-making emphasizes the need to view decision-making not in terms of predetermined designs but as a series of adjustments made in the face of unpredictable events. Often, decisions cannot be predicted in advance but are put together in a sequence as the season unfolds. Farmer decision-making resembles a 'performance' rather than a plan (Richards, 1989). By contrast, on-farm trials are based on a fixed design that rules out improvisation. Farmers do not think this way. They frequently frustrate researchers by adjusting the plan to fit changing circumstances. Researchers usually treat these cases as 'missing data' and omit them from their analyses. We might learn more about our technology, however, if we first tried to understand why farmers changed the plan.

Weeding illustrates that pests cannot be viewed in isolation but must be seen in the context of the farming system, which includes the farm household. Our findings suggest that a major constraint on timely weeding in the Blantyre/Shire Highlands is the lack of effective demand for hired labour. Late weeding thus reflects the major weakness of the farming system, which is that many households cannot generate sufficient cash to make the necessary investment in agricultural production. Until this situation changes, crop losses from weeds are likely to remain a permanent feature of smallholder agriculture in the Blantyre/Shire Highlands.

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DISCUSSION

M. Ritchie. Dr Orr makes the important point that weeding is a performance and, therefore, you cannot validate practices using a set trial approach based on a fixed plan. As researchers we want to assess the outcomes of practices in terms of yield. To do this where farmers adopt diverse decisions on an *ad hoc* basis, we would need to adopt a survey approach with a large sample size to allow for stratification on the basis of the decision types which take place during the season. The decisions made would be recorded and yields measured by crop cuts (or formal plots). There would be quite a high cost to this approach but if farmers are having to make sub-optimal decisions, this approach is the only way to demonstrate the effects of those decisions.

P. W. Kabulizi. Apart from other parameters such as lack of hired labour which contributed to late weeding or no weeding at all, did you also consider the frequent occurrence of funerals or farmers attending funeral ceremonies as one of the factors which contributed to late weeding?

A. O. We did measure labour allocated to 'social investment' activities like funerals, and hope to analyse this soon.

B. Kamanga. Did you find the decision-making for weeding influencing the adoption of technologies in general?

A. O. Generally, seasonal labour bottlenecks, such as that during the 6-week window, are important constraints on the adoption of new technology that requires additional labour. We have examples from the FSIPM Project. These include: high density planting of beans, sealing cracks on sweet potato ridges, and mulching beans.

C. A. Chiumia-Kaunda. Did you find the type of weeds influenced weeding practice or time of weeding?

A. O. We did not ask about the type of weed in relation to time of weeding, or the type of weeding carried out.

J. Lawson-McDowall. What proportion of households are able to hire labour?

A. O. In 1998/99, 21% of households hired labour.

V. Saka. What percentage of your sample gave up weeding despite having some cash?

A. O. Table 1 shows that 17.5% of fields did not receive a second weeding in 1997/98. I do not have the figure yet for 1998/99.

F. M. T. Gondwe. Does the study confirm what gender specialists advocate that women are the sole labour providers for weeding? Is it true that weeding is a woman's task?

A. O. Our results show that participation rates for weeding are higher for women than for men. On average, however, the participation rate for adult males in the second weeding is 73%, so this is not exclusively a woman's task.

R. J. Chapweteka. It seems that your research was based on who weeds and when. It is my experience that many hired labourers do not do a good job. Did you try to find out how effective is the hired labour?

A. O. We have not compared the yield between fields weeded with hired and family labour. Farmers may be willing to accept lower efficiency from hired labour since the cost of *not* weeding is greater than the yield lost as a result of inefficient weeding.

M. M. Kayembe. Usually, when farmers are experiencing a dry spell, they decide to use *kupalira* so that weeds can easily dry. This technique is rarely used during continuous rain. Was the weather considered in recommending the particular techniques? In such trials it is also important to consider the economic implication of each type of weeding as regards yield or disease and pest incidence in each case.

A. O. Kupalira is more appropriate during dry weather, since weeds will not regerminate. When rainfall is continuous, farmers usually delay weeding then use *kusenda* or *kuwojekera* to save time. I agree with the comment about the economic implications of different techniques. The FSIPM Project has data comparing the economic benefits of *kubandira* and *kukwezera*.

R. B. Jones. Did you find farmers were weeding later in the season to control weed seed burden that might affact weeding in subsequent seasons?

A. O. Generally, no. By 8 weeks after planting, the farmers have moved on to other tasks, such as preparing land for sweet potato. Usually no more weeding is given after this period.

Effects of farmer versus researcher-recommended weeding practices on maize yield in Matapwata area, Blantyre/Shire Highlands

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ABSTRACT

An on-farm study to determine the maize yield response to farmer and researcher-recommended weeding practices was undertaken in Matapwata Extension Planning Area (EPA), Blantyre/Shire Highlands in southern Malawi during the 1997/98 cropping season. Twenty-two farmers with either upland or *dambo* fields in Kambuwa and Magomero villages were randomly selected. Four plots were established at each farmer's site. Treatments included fertilizer and weeding regimes. A maize/bean/pigeonpea intercrop was planted. Yield loss from weeds calculated as the difference in grain yield from farmer and researcher-recommended weeding practices varied among the crops. Mean maize yield ranged from 1308 kg/ha on unfertilized farmer-weeded plots to 2342 kg/ha on fertilized researcher-weeded plots. The interaction of weeding and fertilizer was significant ($P<0.05$). Weeds caused yield loss ranging from 1% on unfertilized plots to 22% on fertilized plots. Fertilizer significantly ($P<0.05$) increased maize yield by 59%. Yield losses were particularly associated with a delay in second weeding beyond the recommended 6 weeks after planting (WAP). Beans and pigeonpea yields were generally low. Weed diversity varied across the season. Weed density at 6 WAP was significantly ($P<0.05$) lower in farmer-weeded than researcher-weeded plots. Weed density and diversity were higher in upland than in *dambo* plots. Farmers' decision-making processes for weeding were found to be linked to the previous year's production and governed by biophysical, economic and social factors.

INTRODUCTION

Maize (*Zea mays* L.) is the major food crop in Malawi and is grown either in sole or intercropping systems with legumes and various other crops (Kumwenda and Kabambe, 1995). Struggling to grow a modest crop, farmers contend with various natural constraints, ranging from numerous diseases to insect pests, weeds and nutrient-poor soils. In the Blantyre/Shire Highlands in southern Malawi, average maize yields as low as 1.3 t/ha and a low maize provision ability of 7 months/year were reported (Orr *et al.*, 1997). The importance of weeds as a constraint to crop production in southern Malawi is evidenced by the prevalence of more than 10 out of the 18 most serious weeds of the world listed in *Grassy Weeds – A General Overview* (Terry, 1991). Earlier studies in Malawi indicated that uncontrolled weed growth caused maize grain yield losses of 57–66% (Kumwenda and Kabambe, 1995). The high labour requirement of 36 man-hours/ha expended in weeding and mainly supplied by women and children in Malawi is one of the highest in Africa (Mloza-Banda, 1997). The current research recommendation is for two weeding operations in sole maize, one within 21 days or 3 weeks after planting (WAP) and another before 45 days or 6 WAP (GoM, 1994). While farmers are aware of the potential impact of weeds on crop yield, a survey in the Blantyre/Shire Highlands during the 1996/97 crop year revealed that farmers sometimes find it difficult to weed their crop fields by the research-recommended dates for optimum maize yield (Orr *et al.*, 1997). First weeding had started on 88% of the total area planted to maize among the sample within 3 WAP, but a second weeding had started on only 50% within 6 WAP (Orr *et al.*, 1997).

This on-farm study investigated the effects of different amounts of weeding and fertilizer application levels on the kinds and numbers of weeds and the effect the weeds have on maize yield in different land types. It also explored the occurrence of different weeding practices by smallholder farmers and attempted to list the factors that govern farmers' decision and choice of weeding practices.

MATERIALS AND METHODS

On-farm work to determine a maize yield gap between farmer and researcher-recommended weeding practices was undertaken during the 1997/98 cropping season in Matapwata Extension Planning Area (EPA) (latitude 15°55'S, longitude 35°05'E), Blantyre/Shire Highlands in southern Malawi. Twenty-two farmers with either upland or *dambo* fields were randomly selected in Kambuwa and Magomero villages. Initially an area of 10.8 × 10.8 m was pegged out in each farmer's field that was further staked into four 5.4 × 5.4 m gross plots. Ridges were made by the farmer at a spacing of 0.90 m between ridges. The net plot comprised the middle four ridges discarding one planting station at each edge of the ridge. A maize/bean/pigeon pea intercrop was planted. Maize hybrid variety MH 18 was used (planted at 0.90 × 0.90 m × 3 seeds). Wilt resistant pigeon pea (*Cajanus cajan* L.) variety ICP 9145 (planted at 0.90 × 0.90 m × 3 seeds midway between maize stations) and a dwarf bean (*Phaseolus vulgaris* L.) variety Kalima (planted at 2 seeds/station and 2 stations between maize and pigeonpea) were used as intercrops. Treatments included fertilizer and weeding regimes. Fertilizer was applied in a single dollop application of 50 kg N/ha (mixture of

23:21:0+4S and calcium ammonium nitrate (27%N)) 1 WAP in 2 plots/site to create a soil fertility differential with the other two unfertilized plots. Similarly, 2 plots (fertilized and unfertilized)/site were weeded twice by the researcher at 3 WAP and 6 WAP while the other pair of plots were left to be weeded by the farmer according to usual practice.

Soil samples were taken at depths of 0–15 cm and 16–30 cm of the soil profile to characterize the fields and ascertain the differential in nutrient status between plots before application of treatments. The soil samples were analysed for texture, pH, percentage nitrogen, phosphorus (ppm), potassium (ppm), magnesium (ppm), calcium (ppm), zinc (ppm) and percentage organic matter.

Weeds were sampled prior to weeding at 3 WAP, 6 WAP and at 9–10 WAP. For each treatment a 1 m^2 metal quadrat was placed at random in the plot. The weeds within the quadrat were identified, counted and recorded.

Weed specimens were identified using available texts (Hamilton, 1991; Terry and Michieka, 1987; Vernon, 1983) and wherever necessary, their identity was confirmed at the National Herbarium and Botanic Gardens of Malawi.

Weed plants that could only be identified to the genus level were noted and analysed as such. Only weed species with a mean occurrence of 0.5 plants/m^2 or above for at least two of the three sampling times were used for subsequent evaluation, the other weeds being considered of minor importance in all plots. The weeds were harvested, oven-dried at 80–100°C for 48 h, then weighed to give the dry weight (Lutman *et al.*, 1996). All weed management practices performed by farmers and dates, operators involved, state of field at weeding and possible reasons for any delays were recorded without any interference.

Although the data structure fell into the form of a randomized complete block design with land types as blocks, it was interesting to look at the interaction of land type with each treatment factor. Variation between farms is of particular consequence in so far as the fields were either *dambo* or upland fields. Thus it was necessary to carry out the analysis as though data were from a split unit design with farmers as the main units and plots the sub-units. Land type comprised the main unit 'treatment' while fertilizer and weeding were sub-unit 'treatments'. Farmers were put into different categories based on range of dates to either first or second weeding in the analysis of maize yield. Farmers' responses to questions raised by the researcher regarding every weeding operation done by the farmer during the trial period were modelled into a hierarchical decision tree to outline a pathway of factors influencing weeding decisions (Orr and Koloko, 1998). Other data collected included emergence counts, harvest stand counts, plant heights, crop yields and yield components. Data were, wherever appropriate, subjected to empirical statistics, analysis of variance or analysis of covariance using stand count to adjust maize yield. Yield loss was computed as the difference in grain yield from researcher-recommended and farmer weeding practices expressed as a percentage of the yield from the researcher-weeded plot. Weed species diversity was determined by Berger-Parker diversity index (*d*) which expresses the relative importance of the most abundant species (Magurran, 1988). The Berger-Parker diversity index (*d*) is given by the formula

$$d = N_{max}/N$$

where N = total number of individuals of all species, and N_{max} = number of individuals in the most abundant species. The reciprocal value of the index is used to ensure that the value of the index increases with increase in species diversity.

RESULTS AND DISCUSSION

Soils and rainfall during the 1996/97 and 1997/98 seasons

Soil analysis results indicated that clay loam soils dominated in the *dambo* fields while upland fields had sandy clay loam soils (Table 1). The levels of organic matter, percentage nitrogen (N), magnesium (Mg) and calcium (Ca) were higher in the *dambo* fields compared to upland fields. Phosphorus (P), zinc (Zn) and potassium (K) levels were higher in the upland compared to *dambo* fields. Both *dambo* and upland soils were slightly acidic.

The 1997/98 season was a relatively drier season compared to 1996/97 (Figure 1). Most of the rainfall fell between November and March during 1997/98 and winter rains were almost absent in May. This drastically affected the performance of pigeonpea as the crop had just gone into the reproductive phase. In 1996/97, most of the rainfall fell between December and April and were supplemented by some winter rains in May.

Table 1. Initial mean soil characteristics of experimental sites in Matapwata

Land type	Depth (cm)	Texture	pH (H_2O)	OM (%)	N (ppm)	P (ppm)	Mg (ppm)	K (ppm)	Ca (ppm)	Zn (ppm)
Upland	0–15	SCL	5.4	2.84	0.14	53.50	0.32	0.38	5.8	1.67
(*n*=11)	16–30	SCL	5.4	2.64	0.13	48.60	0.32	0.31	4.57	1.70
Dambo	0–15	CL	5.4	3.56	0.18	28.98	1.09	0.29	14.33	1.14
(*n*=11)	16–30	CL	5.5	3.59	0.18	26.81	0.86	0.30	10.78	1.07

SCL, sandy clay loam soil; CL, clay loam soil; OM, organic matter.
Dambo: low-lying area enveloping a running stream and capable of retaining moisture in the dry season.
Upland: relatively dry area suitable for cultivation only during the rainy season or under irrigation.

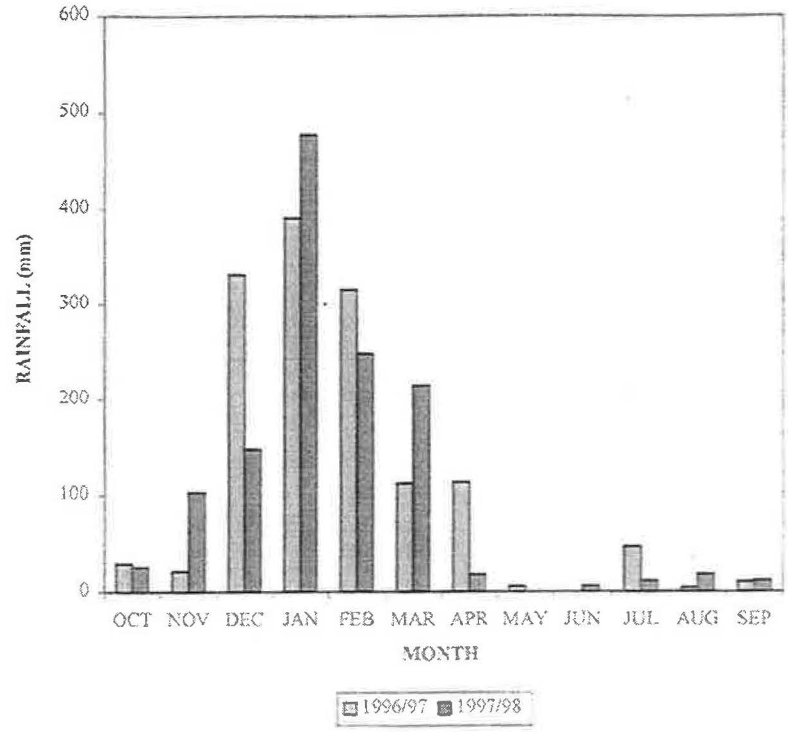

Figure 1. Monthly rainfall distribution for Matapwata during the 1996/97 and 1997/98 cropping seasons. Source: FSIPM sites 1996–98.

Weed response

Weed species diversity

A total of 69 weed species belonging to 53 genera within 25 families were recorded in different combinations in the study plots (Table 2). Four families encompassing Compositae (23%), Gramineae (16%), Cyperaceae (9%) and Amaranthaceae (6%) contributed tremendously (54%) to the weed flora of the area. The prevalence of weed species varied across the cropping season. Thirty-nine weed species were recorded at first weeding (3 WAP), 52 species at second weeding (6 WAP) and 45 species towards the end of the season (9–10 WAP). Out of 26 weed species that were recorded at all sampling occasions and accounted for over 38% of the weed flora, 20 species occurred frequently and were considered to be most important (Table 3). Major broad-leaved weeds included *Acanthospermum hispidum, Ageratum* spp., *Argemone mexicana, Bidens pilosa, Cissampelos mucronata, Commelina* spp., *Euphorbia* spp., *Galinsoga parviflora, Leucas martinicensis, Oxalis latifolia, Sonchus oleraceus, Trichodesma zeylanicum* and *Vernonia poskeana* and these accounted for only 25% of the species.

Major grassy weeds and sedges included *Cynodon dactylon, Cyperus* spp., *Digitaria* spp., *Eleusine indica, Fimbristylis hispidula* and *Leersia hexandra* and accounted for about 10% of the weed flora. Since 1997/98 was a relatively drier season with most of the rains falling between November and March, fewer weeds would be expected than in a wetter season such as 1996/97 when most of the rainfall fell between December and April supplemented by some winter rains in May. Farmers identified *Eleusine indica, Bidens pilosa* and *Panicum maximum* as the most common weeds and *Eleusine indica, Panicum maximum* and *Cynodon dactylon* as the most 'troublesome' weeds in the 1996/97 season (Orr *et al.*, 1997).

At 3 WAP, weed diversity was highest in the upland (reciprocal of $d = 2.28$ for 8.9 species) and lowest in the *dambo* (reciprocal of $d = 2.20$ for 6.2 species) (Figure 2). Unfertilized plots scored low on species diversity (reciprocal of $d = 2.19$ for 7.5 species) than fertilized plots (reciprocal of $d = 2.29$ for 7.7 species). At 6 WAP, a higher diversity of weed species was recorded in the *dambo* than in the upland fields. Fertilized plots showed higher diversity compared to unfertilized plots. These results may imply that first weeding had a greater impact in reducing weed species diversity in the upland as well as in unfertilized plots. At 9–10 WAP weeds were more diverse in the upland plots than in the *dambo* plots. First weeding had a much greater effect in reducing the weed spectrum in farmer-weeded plots than in researcher-weeded plots (Figure 3).

An increase in diversity after second weeding (banking) was due to soil disturbance at banking which brought deeply buried seeds of different weed species to the surface increasing their chance for successful germination and emergence. The highest diversity of weed species occurred in the upland while *dambo* plots had the lowest diversity. According to the Berger–Parker index (*d*), the higher the value of the reciprocal of (*d*), the less the dominance and the higher the evenness of species connoting a high diversity of species (Magurran, 1988).

Table 2. Weed species prevalence by family, sampling time and land type in trial plots in Matapwata during the 1997/98 cropping season

		Sampling time (WAP)*					
		3		6		9–10	
Family	Weed species	U[†]	D[†]	U	D	U	D
Amaranthaceae	*Amaranthus hybridus* L.	–	+	–	–	–	–
	Amaranthus spinosus L.	–	–	–	–	+	–
	Amaranthus thunbergii Moq.	–	–	+	–	+	–
	Celosia trigyna L.	+	–	+	+	–	–
Boraginaceae	*Trichodesma zeylanicum* (Burm.f.) R.Br.	+	+	+	+	+	+
Capparaceae	*Cleome hirta* (Klotzsch) Oliv.	+	–	–	+	–	–
	Gynandropsis gynandra (L.) Briq.	–	–	+	–	–	–
Commelinaceae	*Commelina africana* L.	–	–	–	+	–	–
	Commelina benghalensis L.	+	+	+	+	+	+
	Commelina diffusa L.	–	+	+	+	+	–
Compositae	*Acanthospermum hispidum* D.C.	+	+	+	+	+	+
	Ageratum conyzoides L.	+	+	+	+	+	+
	Ageratum houstonianum Mill.	–	+	–	–	–	+
	Bidens pilosa L.	+	+	+	+	+	+
	Bidens steppia (Steetz) Sherff.	–	–	+	–	–	–
	Conyza canadensis (L.) Cronq.	–	–	+	+	+	+
	Emilia sonchifolia (L.) D.C.	–	–	–	–	+	+
	Galinsoga parviflora Cav	+	+	+	+	+	+
	Launaea cornuta (Oliv. & Hiern.) Jeffrey	–	–	+	+	–	+
	Sigesberkia orientalis L.	–	–	–	–	+	+
	Sonchus oleraceus L.	+	–	+	–	+	+
	Tagetes minuta L.	+	–	+	–	–	–
	Tridax procumbens L.	+	+	+	+	+	+
	Vernonia cinerea (L.) Less.	–	–	–	–	+	+
	Vernonia petersii (Oliv. & Hiern)	–	–	–	+	–	–
	Vernonia poskeana (Vatke & Hildebr.)	+	+	+	+	+	+
Convolvulaceae	*Ipomoea aquatica* Forsk.	–	+	–	–	–	–
Cyperaceae	*Cyperus* spp.	+	+	+	+	+	+
	Fimbristylis hispidula (Vahl) Kunth.	+	+	+	+	+	+
Euphorbiaceae	*Euphorbia heterophylla* L.	–	+	+	–	–	+
	Euphorbia hirta L.	+	+	+	+	+	+
	Phyllanthus leucanthus Pax.	–	–	+	+	+	+
Gramineae	*Cynodon dactylon* (L.) Pers.	–	+	–	+	–	+
	Digitaria gazensis Rendle.	+	+	+	+	+	+
	Digitaria ternata (A. Rich.) Stapf	–	+	+	+	+	+
	Eleusine indica (L.) Gaertn.	+	+	+	+	+	+
	Eragrostis aspera (Jacq.) Nees.	–	–	+	+	+	+
	Eragrostis ciliaris (L.) R.Br.	–	–	+	+	+	+
	Leersia hexandra Sw.	–	+	–	+	–	+
	Panicum maximum Jacq.	–	–	–	+	–	+
	Rhychelytrum repens (Willd.) C.E. Hubbard.	+	+	+	+	–	–
	Rottboellia cochinchinensis (Lour.) Clayton.	+	+	–	–	+	+
	Rottboellia exaltata L.f.	–	–	+	+	–	–
Lamiaceae	*Leonotis mollisima* (L.)	–	–	–	+	–	–
	Leucas martinicensis (Jacq.) R.Br.	+	+	+	+	+	+
	Ocimum canum Sims.	–	–	+	–	+	+
Leguminosae	*Crotalaria* spp.	+	–	–	+	+	–
Lythraceae	*Ammannia prieuriana*	–	–	–	–	–	+
Malvaceae	*Hibiscus cannabinus* L.	–	–	–	+	–	–
	Sida acuta Burm.f.	+	+	+	+	+	+
Menispermaceae	*Cissampelos mucronata* A.Rich.	+	+	+	+	+	+
Molluginaceae	*Mollugo cerviana* (L.) Ser. ex D.C.	+	–	–	–	–	–
Nyctaginaceae	*Boerhavia diffusa* L.	–	–	–	+	–	+
Oxalidaceae	*Oxalis corniculata* L.	–	–	+	–	–	–
	Oxalis latifolia Kunth.	+	–	+	+	+	+

continued

Table 2. continued

Family	Weed species	Sampling time (WAP)* 3 U[+]	3 D[+]	6 U	6 D	9–10 U	9–10 D
Papaveraceae	*Argemone mexicana* L.	+	–	+	+	+	+
Papilionaceae	*Mucuna pruriens* (L) D.C.	+	+	+	+	–	–
Polygonaceae	*Oxygonum sinuatum* (Meisn) Dammer	+	+	+	+	–	–
Portulaceae	*Portulaca oleracea* L.	–	+	+	+	–	+
Rubiaceae	*Oldenlandia herbacea*(L.) Roxb.	–	–	–	–	+	+
	Spermacoce sinensis (Klotzsch.) Hiern.	–	–	–	–	+	+
Solanaceae	*Nicandra physaloides* (L.) Gaertn.	–	–	+	–	–	–
	Solanum incanum L.	–	–	+	–	–	–
Scrophulariaceae	*Striga asiatica* (L.) Kuntze	–	–	–	–	+	+
Tiliaceae	*Corchorus olitorius* L.	+	+	–	–	+	–
	Triumfetta annua L.	+	–	–	–	–	–

*WAP, weeks after planting of crops.
[+]Land type: U, upland; D, *dambo*.
–, Weed species absent; +, weed species present.

Table 3. The dominant weed species observed in trial plots by village and sampling time in Matapwata during the 1997/98 cropping season

Family	Weed species	Sampling time (WAP)* 3 K[+]	3 M[+]	6 K	6 M	9–10 K	9–10 M
Boraginaceae	*Trichodesma zeylanicum* (Burm.f.) R.Br.	+	+	+	+	+	+
Commelinaceae	*Commelina benghalensis* L.	+	+	+	+	+	+
	Commelina diffusa L.	+	–	+	+	+	+
Compositae	*Acanthospermum hispidum* D.C.	+	+	+	+	+	+
	Ageratum conyzoides L.	+	+	+	+	+	+
	Ageratum houstonianum Mill.	–	+	–	–	–	+
	Bidens pilosa L.	+	+	+	+	+	+
	Galinsoga parviflora Cav	+	+	+	+	+	+
	Tridax procumbens L.	+	+	+	+	+	+
	Vernonia poskeana (Vatke & Hildebr.)	+	+	+	+	+	+
Cyperaceae	*Cyperus* spp.	+	+	+	+	+	+
	Fimbristylis hispidula (Vahl) Kunth.	+	+	+	+	+	+
Gramineae	*Cynodon dactylon* (L.) Pers.	–	+	–	+	–	+
	Digitaria gazensis Rendle.	+	+	+	+	+	+
	Digitaria ternata (A. Rich.) Stapf	+	–	+	–	+	+
	Eleusine indica (L.) Gaertn.	+	+	+	+	+	+
	Leersia hexandra Sw.	–	+	–	+	–	+
Lamiaceae	*Leucas martinicensis* (Jacq.) R.Br.	+	+	+	+	+	+
Oxalidaceae	*Oxalis latifolia* Kunth.	+	+	+	+	+	+
Papaveraceae	*Argemone mexicana* L.	–	+	–	+	–	+

*WAP, weeks after planting of crops.
[+]K, Kambuwa village; M, Magomero village.
–, weed species absent; +, weed species present.

Weed density and dry weight

Weed density at 3 WAP was not significantly ($P<0.05$) influenced by land type, fertilizer and their interactions. At 6 WAP, the interactions of land type and treatments were not significant but weeding and land type were significant ($P<0.05$) and acting independently. Weed density was higher in researcher-weeded plots (397 plant/m^2) than farmer-weeded plots (315 plants/m^2), and also in the upland (426 plants/m^2) than in the *dambo* (282 plants/m^2) plots. Lower weed density observed on farmer-weeded plots may have resulted from thorough weeding by the farmer compared to

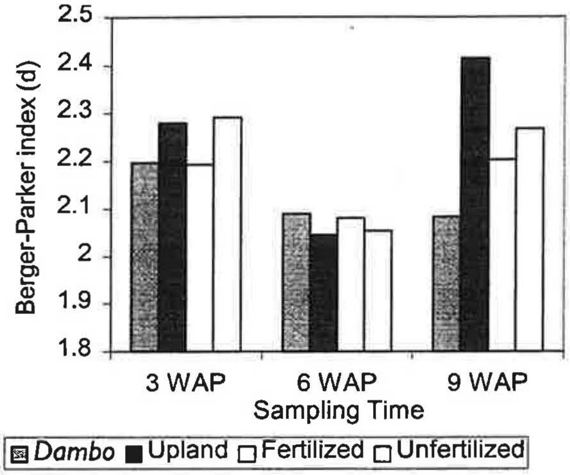

Figure 2. Weed floral diversity in Matapwata as influenced by land type and by fertilizer during the 1997/98 cropping season (plotted values are those of the reciprocal of d*).*

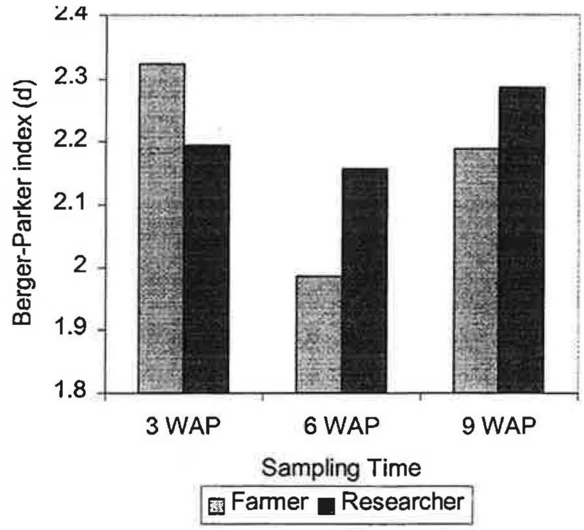

Figure 3. Weed floral diversity in Matapwata as influenced by weeding regime during 1997/98 cropping season (plotted values are those of the reciprocal of d*).*

that done by hired labourers on researcher-weeded plots. Hired labourers tend to weed less thoroughly than the farmers themselves as payment is made according to the area weeded and not to the time spent. Weed density at 9–10 WAP was not significantly affected by treatments.

Researcher-weeding decreased weed dry weight accumulation at 6 WAP or banking. Fertilizer significantly ($P<0.05$) increased weed dry weight both at 3 WAP and 6 WAP (Table 4). This implies that in the presence of fertilizer and delays in first weeding both the crop plants and weeds can benefit from the input of nutrients supplied by fertilizer.

Delays in both first weeding and second weeding by farmers and the use of different weeding practices, such as *kupalira, kusenda, kukwezera, kuzulira, kubandira* or a combination of these as dictated by the farmers' social and economic circumstances, may have resulted in high weed dry weight accumulation in farmer-weeded plots. A sudden increase in weed dry weight observed between 6 WAP and 9–10 WAP may be attributed to the wide variation in farmer timing of weeding which allowed weeds more time to grow and accumulate more dry weight.

Researcher weeding resulted in a significant ($P<0.05$) reduction in weed dry weight at 9–10 WAP. Removal of weeds at 3 WAP and 6 WAP on researcher-weeded plots enhanced the competitive ability of crop plants against weeds, thereby suppressing subsequently emerging weeds. Unexpectedly, there was a significant ($P<0.05$) reduction in weed dry weight at 9–10 WAP in fertilized plots weeded by the researcher. The application of fertilizer resulted in fast growth of the crop plants, thereby exerting smothering effects on weeds and hence a reduction in weed dry weight. Weed dry weight at 9–10 WAP was significantly ($P<0.05$) lower in the upland (62.9 kg/ha) than in the *dambo* (132.8 kg/ha), probably because of reduced inter-specific competition due to low species diversity in the *dambo*. The interactions of land type and treatments were not significant.

Grain yields

Grain yield response to treatments was variable across the three crops. Overall mean maize grain yield ranged from 1308 kg/ha on unfertilized farmer-weeded plots to 2342 kg/ha on fertilized researcher-weeded plots (Table 5).

Table 4. Effect of fertilizer on weed dry weight (kg/ha) at different sampling times

	Fertilizer (F) (kg N/ha)								
	3 WAP			6 WAP			9–10 WAP		
Weeding (W)	**0**	**50**	**Mean**	**0**	**50**	**Mean**	**0**	**50**	**Mean**
Farmer	26.9	51.5	39.2	30.9	43.0	37.0	139.9	107.8	123.9
Researcher	38.9	46.8	42.9	24.4	34.7	29.5	89.7	49.0	69.4
Mean	32.9	49.3	27.7	39.0	114.8	78.4			
$LSD_{0.05}$ (W)		NS			NS			28.5	
$LSD_{0.05}$ (F)		14.5			10.5			27.3	
$LSD_{0.05}$ (W × F)		NS			NS			NS	
CV%		81.5			73.4			66.7	

Table 5. Overall effect of weeding and fertilizer on maize grain yield (kg/ha)

	Fertilizer (F) (kg N/ha)		
	Weeding (W)		
	0	50	Mean
Farmer	1308	1838	1573
Researcher	1327	2342	1835
Mean	1318	2090	
$LSD_{0.05}$ (W)			208
$LSD_{0.05}$ (F)			202
$LSD_{0.05}$ (W × F)			289
CV%			28.0

Maize yield loss on farmer-weeded plots was 14% (262 kg/ha) of the yield obtained from researcher-weeded plots. Grain yield loss caused by weeds ranged from 1% (19 kg/ha) in unfertilized maize to 22% (504 kg/ha) in fertilized maize. The grain yield benefits from optimal timely weeding depended on the use of fertilizer. Although the interaction of weeding, fertilizer and land type was significant ($P<0.05$) for maize yield, this interaction was only apparent in the upland plots and was not observed in the *dambo* plots (Figure 4). In yield terms, researcher weeding was superior to farmer weeding in upland fertilized maize but not in unfertilized maize. Fertilizer application either improved the supply of nutrient elements to the crop or resulted in bigger and highly competitive maize plants in accessing and translocating nutrients to grain. Fertilizer caused a 59% (772 kg/ha) boost in maize grain yield with a 77% (1015 kg/ha) yield increase recorded on researcher-weeded plots and only 41% (530 kg/ha) yield increase achieved on farmer-weeded plots. These results correspond to an earlier report on maize yield studies in Malawi that timely weeding is very important if maize plants are to respond successfully to inorganic fertilizers (Benson, 1997). However, high cost and absence of loans are the most prohibitive aspects limiting farmers' access to inorganic fertilizer in Malawi. Plant height at harvesting was not significantly influenced by weeding.

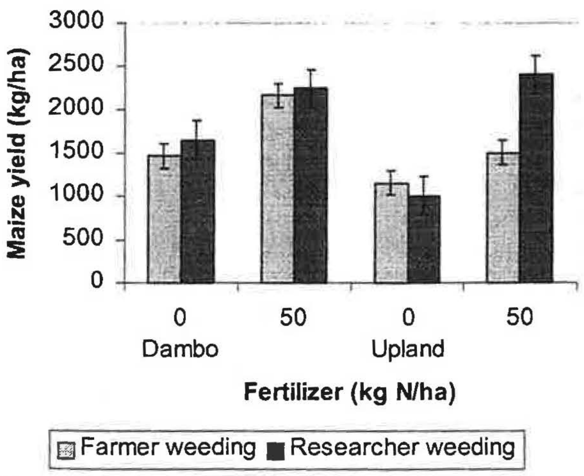

Figure 4. Maize grain yield as influenced by weeding and fertilizer in dambo *and upland plots during the 1997/98 cropping season.*

Table 6. Effect of weeding and fertilizer on mean maize stand count at harvest per plot

	Fertilizer (F) (kg N/ha)		
	Weeding (W)		
	0	50	Mean
Farmer	37	37	37
Researcher	34	38	36
Mean	35	37	
$LSD_{0.05}$ (W)			NS
$LSD_{0.05}$ (F)			1.6
$LSD_{0.05}$ (W × F)			2
CV%			12.0

The interaction of weeding and fertilizer significantly ($P<0.05$) affected survival of maize plants (Table 6). Maize plant stand at harvesting was highest on fertilized researcher-weeded plots and lowest on unfertilized researcher-weeded plots. When harvest stand count was used as a covariate to adjust maize yield, the results were not significant ($P<0.05$) for the different groups of farm sites based on weeding dates. Other pests, such as whitegrubs, might have caused plant mortality thus reducing maize harvest stand count and yield.

Effects of delayed weeding at first and second weeding on maize yield

The period from planting to first weeding by farmers ranged from 15 days to 34 days (mean 20 ± 0.4 days). First weeding in *dambo* plots started 9 days earlier than in the upland. Similarly, second weeding (banking) in the *dambo* started 8 days earlier than in the upland plots signifying a much earlier flush of weeds in the *dambo* than upland fields. The period to second weeding (banking) ranged from 39 days to 78 days from planting (mean 51 ± 0.8 days). Only two of the farmers participating in the trials left their fields unweeded at second weeding citing inadequate family labour and food insecurity as the major reasons for failure. Weeding was suspended by the farmer in order to sell labour in cash or kind to ensure survival of the household. This implies that farmers can hardly afford to invest a substantial part of their labour into future yield benefits if their daily survival is threatened (Orr *et al.*, 1997).

A generally decreasing trend in maize yield was observed following delays in either first or second weeding (Tables 7 and 8). A week's delay in first weeding than recommended caused about 34% (800 kg/ha) loss in maize yield in the upland and 38% (642 kg/ha) in the *dambo* plots. Plots where the farmer implemented first weeding much earlier than the researcher in the *dambo* gave 22% (373 kg/ha) higher maize yield than the plots weeded according to researcher-recommended date. This suggests the need for an even earlier start in first weeding to achieve high maize yield.

Similarly at second weeding, plots banked by 6 WAP gave significantly ($P<0.05$) higher maize yield than those weeded beyond this date. A delay in banking by 2 weeks caused 18% (229 kg/ha) loss in maize yield on unfertilized plots

Table 7. Effect of early and delayed first weeding on maize grain yield in *dambo* and upland plots

Days from planting to first weeding	Maize yield (kg/ha)		
	Land type (L)		
	Dambo	Upland	Mean
15–17 (F)*	2048	1167	1608
18–20 (R)*	1675	2342	2008
21–25 (F)	1674	1752	1714
>25 (F)	1033	1542	1288
Mean	1608	1701	
$LSD_{(0.05)}$ within (L)			443
CV (%)			37.5

F, range for farmer; R, range for researcher.

Table 8. Effect of early and delayed second weeding (banking) on maize grain yield in fertilized and unfertilized plots

Days from planting to second weeding (W)	Maize grain yield (kg/ha)		
	Fertilized	Unfertilized	Mean
39–42 (R)*	2298	1308	1803
43–50 (F)*	2091	1784	1937
51–55 (F)	1521	1153	1337
>56 (F)	1696	1079	1388
Mean	1902	1331	
$LSD_{(0.05)}$ within (W)			583
CV (%)			38.0

*F, range for farmer; R, range for researcher.

and 26% (602 kg/ha) yield loss in fertilized maize. The unexpected increase in maize yield obtained from plots banked beyond 56 DAP may be attributed to the contribution of decomposing weed plants from early first weeded plots.

The yield of bean and pigeonpea was generally low. Mean bean yield ranged from 55 kg/ha to 75 kg/ha while pigeonpea yield ranged from 3 kg/ha to 9 kg/ha across the treatments. The effect of treatments and their interactions with land type were not significant ($P< 0.05$) on bean and pigeonpea yield. An early attack by *Ootheca* spp. and the presence of *Alcidodes* spp. and beanfly (*Ophiomyia* spp.) on the bean crop may have reduced yields. Low pigeonpea yield may be attributed to reduced plant stand at harvest caused by heavy plant mortality across the season due to damage by *Fusarium* and stem canker complex alongside nematodes and whitegrubs. Early cessation of rains and the absence of winter rains prevented effective anthesis and podding of the pigeonpea plants resulting in low yields.

Economic analysis and implications for farmers' weeding practices

The highest net returns to labour and fertilizer were realized from weeding according to current research recommendations compared to farmer weeding (Figure 5). Researcher weeding and the application of fertilizer resulted in a net benefit of MK6192.55 followed by farmer weeding with fertilizer (MK4410.25). Fertilized farmer-weeded plots performed similarly to unfertilized researcher-weeded plots emphasizing the need for more timely weeding to optimize returns to labour and fertilizer. The lowest net returns were obtained from unfertilized farmer-weeded plots. However, uptake of this strategy by farmers in Matapwata is unlikely as the farming system appears to be trapped in a cycle of low productivity and low soil fertility. Low levels of use of external material inputs have been reported in the farming system in the Blantyre/Shire Highlands (Orr *et al.*, 1997).

The cash-strapped smallholder farmers are likely to favour multi-beneficial low input technologies, such as green manures which, while suppressing weeds, will help to restore soil fertility. Similarly, manipulation of planting densities in intercrops, and competitive crop cultivars will reduce the labour demand for weeding by smothering the weeds thus releasing family labour to other household survival activities. Since most farmers use family labour to weed, a true opportunity cost of ideal weeding at farmers' level of decision-making could still be expected. If weeding is deferred to a later date, some cash can be earned by *ganyu* and this represents an added benefit of late weeding. As rational decision-makers, farmers conduct a cost-return analysis regarding the likely benefit from an activity before any re-

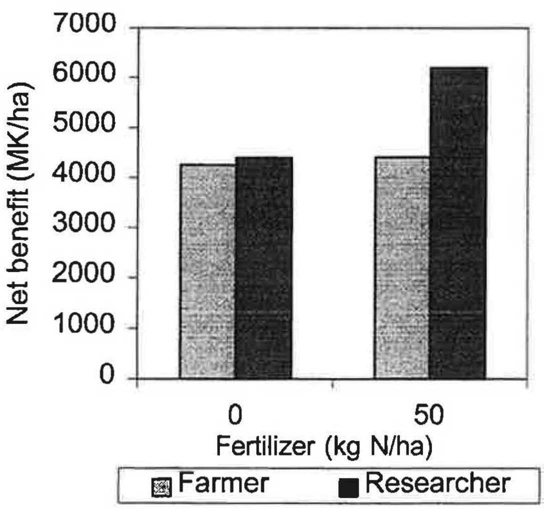

Figure 5. Cost and return analysis for weed control practices used in maize production during the 1997/98 cropping season. GR, gross returns; TVC, total variable cost computed from labour and fertilizer cost. Exchange rate: 1US$ = MK17.3060 as of September 1997. Price as of 1997/98: labour, MK0.10/four maize hills; fertilizer, CAN(27% N), MK356.25/50 kg bag; 23:21:0 + 4S, MK487.50/50 kg bag. Farm gate prices (MK): maize, 4.20/kg; bean, 8.00/kg; pigeonpea, 4.50/kg. Net yield = gross yield–20% downward adjustment (Benson et al., 1997). Gross returns = net yield ´ unit price.
Net benefit = GR – TVC.
Fertilizer cost is 1.25 times ADMARC price in 1997/98 to cater for opportunity cost of farmers' time and transport. Weeding cost is ganyu labour charge of MK0.10/four maize planting stations (3.6 m row) in Matapwata during the 1997/98 cropping season and assuming 37 037 maize plants/ha, for a per hectare cost of MK618.00.

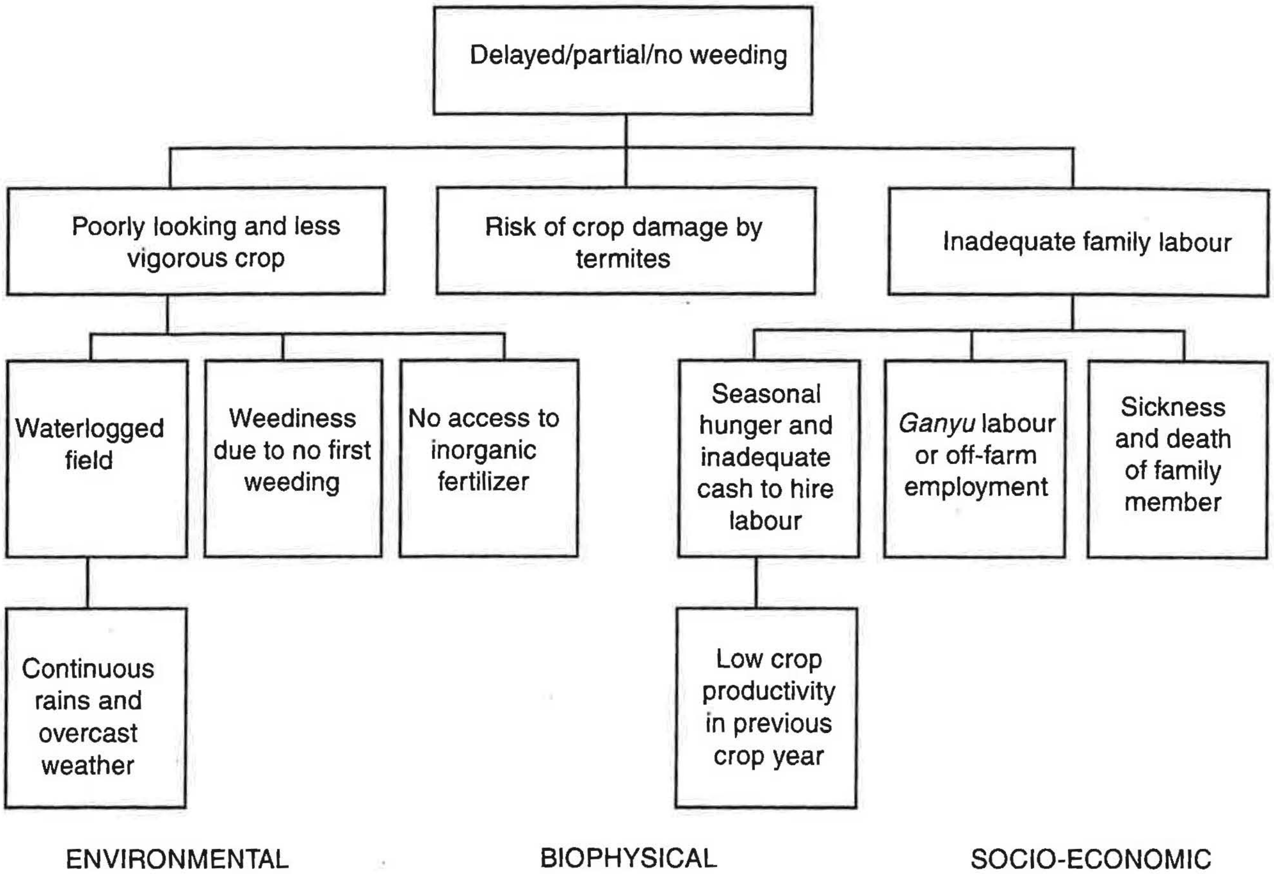

Figure 6. Pathway analysis of the main determinants of smallholder farmer decision-making process for weed control.

sources can be committed to its implementation (Lawas, 1998).

From direct observation and interaction with farmers during the trial period, the decision-making process for weeding and the choice of weeding practices was very complex among smallholder farmers in Matapwata. A decision tree analysis suggests that delays in weeding were related to various factors, such as waterlogging and inadequate family labour within the production system. These factors were either environmental, biophysical or socio-economic and sometimes linked to crop productivity in the previous season (Figure 6).

The most common weeding practices recorded in farmers' fields included *kupalira* for first weeding and *kubandira* for second weeding. Other weeding practices recorded included *kuwojekera* or *kusenda, kupala* or *kukhwazira, kukwezera, kuzulira* and *mbwera* or *bwanyula* (Table 9).

A variety of weeding practices offers room to manoeuvre in improving crop productivity among smallholder farmers if yield benefits accrued to each practice were evaluated. Farmers would not implement weeding practices based only on effectiveness of weed control but also on the amount of labour required by any particular weeding practice. Farmers are unlikely to use an individual weeding practice in isolation but resort to a combination of different practices in the same weeding operation to reconcile the various demands on family labour. Recognition of first weeding as *kupalira* and second weeding as banking (*kubandira*) by formal research in Malawi (Mloza-Banda, 1997) only disregards and downgrades the diversity in weeding practices that exists in the Blantyre/Shire Highlands. Extension officers need to be aware of the farmers' own innovative means of combating weeds and not to make blanket recommendations based on researchers' understanding of first weeding as a uniform operation known as *kupalira* and second weeding as another uniform operation known as banking (*kubandira*). This study has shown that driven by natural as well as socio-economic circumstances, farmers have either forced an evolution of alternatives to *kupalira* and banking to cope with weeds or otherwise have abandoned the field.

CONCLUSIONS

The conclusions from this work are that farmers lost 262 kg/ha (14%) in maize yield by delaying weeding beyond researcher-recommended dates for first and second weeding. Potential still exists to improve crop yield by adherence to research weeding recommendations and the application of fertilizer. Net returns to labour expended in weeding were higher where maize received fertilizer than in unfertilized maize.

A wide spectrum of weed species prevailed in Matapwata during the 1997/98 season. More importantly, there were indications that weed flora was more diverse in the upland than in the *dambo* fields. Diversity was higher mid-season

Table 9. An inventory and description of weeding practices for Matapwata based on observation in farmers' fields during the 1997/98 season

Weeding practice	Description of practice and when done
First weeding	
Kupalira or *Kapalepale**	Hand-hoe weeding by scraping the sides of the two ridges and spreading the weeds in the weeded intervening furrow to dry them out. Practice is often done on sunny days to smother weeds by the sun's heat.
Kusenda or *kuwojekera*	Hand-hoe weeding whereby weeds from the side of one ridge are hauled downwards from the maize planting station and transferred and buried on the side of the next ridge. The practice is done to reduce time required for banking in case the farmer is late.
Kupala or *kukhwazira*	Practice whereby weeds are scraped from the side of the ridge without moving the soil and leaving the weeds to dry. It is done usually when the farmer could not start weeding in time and still wants to implement late weeding.
Second weeding	
Kubandira (banking)	Practice of covering the weeds by soil drawn from the furrow to rebuild adjacent ridges and support the plants. It is usually done when the soil is still wet.
Kukwezera	Scraping weeds from one side of the ridge upwards towards the planting station without covering the weeds with soil. It is a common practice in termite prone fields.
Kuzulira	Pulling up tall weeds by hand and scraping off smaller ones from the sides of the ridge with a hoe without disturbing those weeds in the furrow. The scraped weeds are then laid on top of the adjacent ridges. The practice is usually done under waterlogged conditions. It may also involve hand-pulling tall weeds and laying them down in the furrow or heaping them before *kupalira* or banking. The practice is often done in fields situated on hill slopes.
Bwanyula or *mbwera*	Laying stripped-off bottom leaves of maize plants in the furrow, then covering them with soil from the old ridges to create a new ridge for planting a relay crop of bean or field pea. It is dependent on residual moisture of the soil as it takes place towards the end of the growing season.

than in the early and late season. Additional effort using labour-saving techniques may be required for weeding in the upland since most smallholder crops are produced in the upland areas. The influence of weeding and fertilizer on weed floral diversity was not clearly discerned, probably because a single season's trial did not allow the residual effects of these treatments to be studied.

There was considerable variability in weeding time and farmer practices for first weeding and second weeding (banking) reflecting the complexity of weeding decisions. Farmers' weeding practices comprised *kuwojekera, kuzulira, kupala, kukwezera,* and *bwanyula* with various permutations and choice of practice depended on a wide range of factors. Researchers' understanding of farmer weeding practices, as a uniform first weeding (*kupalira*) followed by banking (*kubandira*), downgrades and disregards reality of the current situation. Weed control techniques that provide the most returns to labour and time while conserving resources for survival of the farming household are likely to be adopted.

Further work is required to confirm these findings in different agro-ecologies to establish the basis for farmer choices of weeding practices and update weed control recommendations for Malawi.

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DISCUSSION

I. Hoeschle Zeledon. Did the project encourage farmers to do the second weeding and to do it in time? If yes, how did the project communicate this message to the farmers?

C. R. Riches. Within this experiment farmers were to carry out the weeding they could manage on the plots. An ideal level of weeding was imposed (using labourers) on the researcher-weeded plots. There was a check kept on the weeding status of the surrounding field to see whether the farmer was treating the plots differently from his/her normal practice.

E. Chilembwe. You choose a farmer and a researcher in your weeding experiment. Were all the farmers resource-poor or did some have adequate cash? Was the researcher chosen as a researcher or was he representing farmers with adequate resources?

C. R. R. The researcher was representing the recommendations on how many times to weed and how frequently. The farmers were in general resource-poor although some had resources.

Options for management of witchweeds in cereals for smallholder famers in Malawi

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ABSTRACT

Field infection by parasitic weeds, particularly *Striga asiatica,* is one of the major constraints in maize production in Malawi. Other constraints include declining soil fertility and pests and diseases, such as stem borers, termites, blights and rusts. Farmers' resource base in Malawi is low and hence, only an integrated control approach utilizing low-cost technologies is feasible. This paper discusses farmers' knowledge of the biology of witchweeds as an important prerequisite for management approaches. Four categories of control strategies are presented and discussed, namely reducing seed production and infection, reducing the seed bank in soil, reducing crop loss and integrated control. Selected research results, such as the effects of fertilizer application, crop rotation, intercropping and resistant varieties, are presented to show the potential effects of these components to integrated management.

INTRODUCTION

Witchweeds are parasitic plants, drawing their water and food resources from host plants, mostly through the root system. *Striga* is the most important genus affecting cereals. *Striga* species recorded in Malawi are *S. asiatica, S. aspera, S. euphrasioides, S. gesnerioides,* and *S. forbesii.* There are also some witchweeds which affect legumes, two of these are important in Malawi. *Striga gesnerioides* (Willd.) Vatke. is mostly of economic significance on cowpea but also attacks tobacco, indigo and *Tephrosia. Alectra vogelii* attacks many legumes such as cowpea, bambara groundnut, common bean, mung bean, dolichos bean, velvet beans (mucuna or kalongonda), but apparently not pigeonpea (Ramaiah *et al.*, 1983)

Witchweeds cause serious yield loss in cereals and legumes. Cereals are the staple food for most countries in Africa, including southern Africa and Malawi. Legumes are an important source of protein and cash for most smallholder farmers in Malawi.

One of the reasons why *Striga* incidence is increasing is because of the continuous cropping of maize and other cereals and legumes, which is necessitated by land constraints. The minimal use of cash inputs, such as fertilizers and herbicides, also contributes. Losses depend on the level of infection, susceptibility of genotype, soil fertility and crop management. In maize it has been estimated that each *Striga* plant per m^2 causes 0.1% yield loss. Recent research results under farmers' conditions in Malawi show an 84% yield increase with partial control of *Striga* (Table 1). Total yield loss is possible in some cases. Therefore, most of the efforts to increase food security in Malawi through increased maize production are thwarted by this problem. At Chitedze Research Station, however, there was hardly any yield loss, and yield levels were higher, indicating that for soils with high productivity and high management levels, the impact of witchweeds is minimal. A witchweed management protocol should, therefore, address soil productivity in general.

Being parasitic, witchweeds draw nutrients and water from the host crop. It is established that they inflict a toxic effect on the host which reduces its photosynthetic capacity. For this reason, host plants are water stressed, and most of the damage to the host occurs before parasite emergence.

BIOLOGY OF WITCHWEEDS

The biology of witchweeds is unique, and it is important to understand the basic concepts in order to appreciate some of the rigorous requirements for their control.

Seed biology

A single plant can produce up to 50 000 seeds, hence rapid build-up of the seed bank is possible. Seeds remain viable for up to 15–20 years. They are tiny and dust-like (0.2–0.4 mm diameter). Mature seeds must go through a period of dormancy (after ripening) before they can germinate. This dormancy can be broken by exposure to high temperatures and relative humidity. The significance of this dormancy is that seeds cannot germinate soon after crop harvest. Also, seeds will not germinate until triggered by a chemical stimulant; host crops and some non-host crops naturally produce this stimulant.

Host infection

Seeds of witchweed require exposure to warm (22–30°C) moist conditions for about 10–21 days before they can ger-

Table 1. The effect of partial protection against *Striga* with imazethapyr (30 g/ha) on *Striga* emergence and maize yield at Chitedze Research Station and farmers' fields at Mponela

Variable and date	Chitedze		Mponela	
	Treated	Untreated	Treated	Untreated
Striga count (m^{-2}), 69 and 61 DAP	0.19	5.23	0	0.93
Striga count (m^{-2}), 85 and 89 DAP	4.0	19.3	4.9	37.4
Striga count (m^{-2}), 102 and 112 DAP	14.8	27.7	10.5	33.1
Maize yield (kg/ha)	4961*	5004	2345	1471
Percentage yield gain	–	–	–	84
Percentage yield loss	–	–	37	–

*15 ears were stolen from this treatment therefore further comparisons were not carried out.
DAP, days after planting.

minate ('conditioning'). Once triggered by the stimulant, the radicle of a germinated *Striga* seed grows towards the host root. The young seedling (germling) is attached to the host root by the haustorium, an attachment organ. The germling or seedling dies within 4 days after germination if it cannot attach to a host.

Nature of damage

Striga infection causes reduction in some growth hormones, biosynthetic enzymes and photosynthesis and it is this that results in most damage to the host rather than the resources it draws from the host. Graves *et al.* (1989, 1990) reported that 80–85% of the growth reduction in sorghum and millet was due to decreased photosynthesis and only 20% by actual uptake by *S. hermonthica*. Reduced crop growth has been observed as early as within 4 days of infection (Gurney *et al.*, 1995). Kabambe (1997) reported 32% growth reduction after 50 days in maize infected with *S. asiatica* at planting, while the dry weight of the *Striga* was negligible.

Biological concepts in management

Knowledge of these biological concepts is important in many ways. For example, by knowing that *Striga* may not germinate before conditioning, it is possible to escape damage by utilizing the first 14–21 days of growth to grow a healthy crop. Employing other factors which delay *Striga* germination will further extend this period (see control approaches). It also means varieties with low stimulant production may be resistant and that seed depletion may be possible with plant species that trigger germination but prevent attachment (a concept referred to as trap cropping in the control section). Also, because seeds can remain viable for many years, simply resting the land may not lead to eventual seed demise due to natural death. Figure 1 shows a simplified life cycle of *Striga* which may be used to plan the easiest and most effective point to intercept *Striga* growth, development or multiplication.

CONTROL CATEGORIES

Witchweed control practices can be classified into four

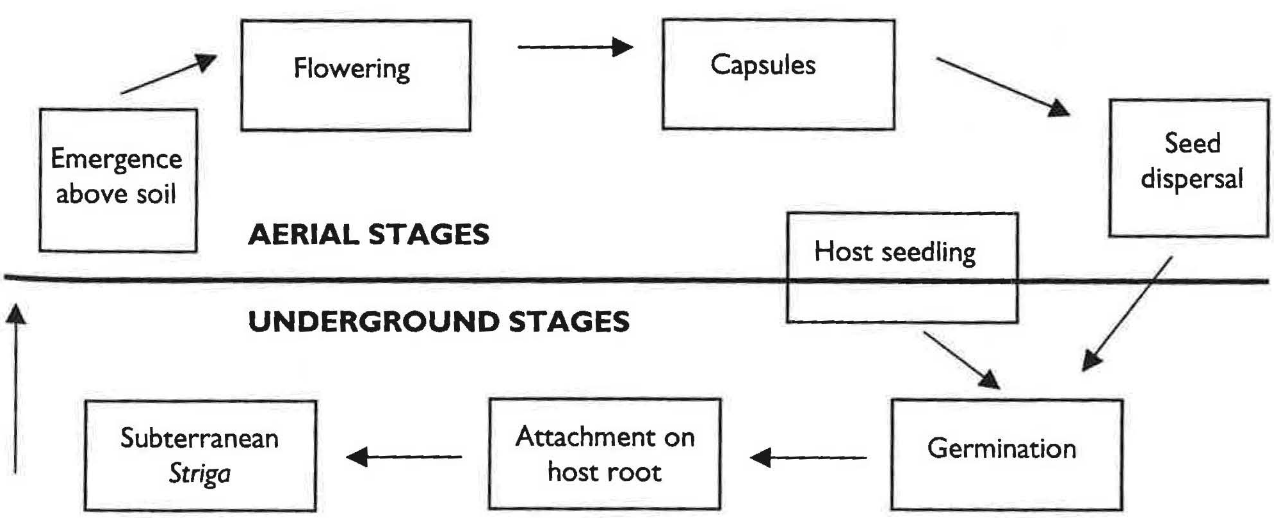

Figure 1. Life cycle of Striga.

major categories. These are based on the major goal, theme or mechanisms that the practices or different strategies aim to achieve. However, the individual strategies overlap between categories. Therefore, after these categories and goals are listed, the detailed discussions are based on strategies.

Prevention of spread and infection of clean land

The goals for strategies in this category are to prevent the spread of *Striga* to clean land, and to reduce or prevent more seed being produced and returned to infected land. Control strategies that will achieve these goals are keeping uninfected land clean, reducing seed return to soil, use of resistant (low support) varieties, animal manure and nitrogen application.

Reducing the seed bank in the soil

The goal of strategies in this category is to facilitate or cause the rapid demise of *Striga* seed in the soil, while preventing more seed being returned to the soil. Strategies include the use of resistant varieties, nitrogen fertilizers, use of trap crops and chemical control.

Reducing crop loss

The goal is to minimize crop loss for farmers who must grow a susceptible host for household food security. Strategies that may be employed include good husbandry practices, use of tolerant or early maturing varieties and chemical control.

Integrated control

The goal of integrated control is to utilize every available resource to control witchweeds.

CONTROL OPTIONS

Keeping uninfected land clean

The objective of this strategy is to keep uninfected land free of witchweed. Where there is mild infection, witchweed plants can be pulled by hand and disposed of by burning or burying at a depth of 45 cm or more. One should always walk or work from clean land to uninfested land. Implements used on infested soil should be cleaned before use on clean land. Where seed is conserved on the farm, only clean seed should be used. If seed is harvested from infected fields, contamination at harvest should be avoided. Ears or pods should not be thrown on the ground as they may admix to seed; they should be harvested directly into bags or baskets. Important means of seed dispersal are water, seed and adherence to animals and implements. Therefore, properly constructed soil conservation structures are useful in confining *Striga* to one area.

Reducing seed return to the soil

The goal of this strategy is to stop the *Striga* plant from maturing and reseeding. Hand-pulling will help as outlined above. Chemicals, such as metolachlor (e.g. Dual) and pendimethalin (e.g. Prowl), though expensive, can be employed. Other chemicals, such as old engine oil, can be used. These prevent *Striga* from transpiring, resulting in sudden death due to heat stress. There is also potential to utilize biological herbicides or insects that are specific only to witchweeds.

Use of resistant varieties

Resistant maize varieties are presently not available. However, Table 2 shows the yield and *Striga* incidence

Table 2. Effect of variety on *Striga* emergence per m^2 at 55, 66 and 92 DAP and on grain yield

Variety	*Striga* no. 55 DAP	*Striga* no. 66 DAP	*Striga* no. 92 DAP	Grain yield (kg/ha)
1 = TZ 96STR Syn-W	1.11	18.5	35.9	4097
2 = TZ 96STR yn-Y	0.12	16.7	28.8	4017
3 = Acr. 93TZL Comp.1-W	0.06	7.7	27.2	4613
4 = TZL Comp.1 C4	0.31	10.7	20.8	5533
5 = IWD STR.CO	0.68	15.7	38.0	5113
6 = IWFSTR . CO	1.23	20.3	32.8	6572
7 = STR.EV.IWD	0.31	19.0	41.0	4428
8 = STR.EV.IWF	2.47	15.5	26.7	6620
9 = TZB-SR (susc.)(RE)	0.43	17.2	54.5	4840
10 = TZB-SR (susc. hybrid)	1.79	38.0	74.0	3845
11 = 8338-2 (susc. hybrid)	0.31	11.2	30.8	4903
12 = Masika (local check)	0.31	10.5	48.5	6617
Mean	0.76	16.8	38.3	5108
LSD (5%)	1.79	7.2	25.0	815
P	0.202	0.032	0.009	<0.001
CV%	164	14.7	45.5	16

DAP, days after planting.

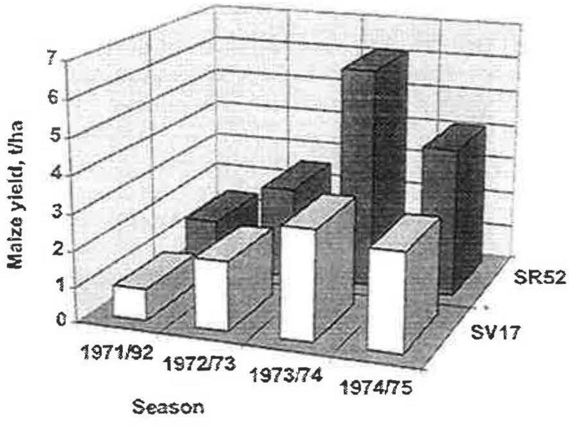

Figure 2. Yield of composite (SV17) and hybrid (SR52) maize varieties under Striga *infection.*

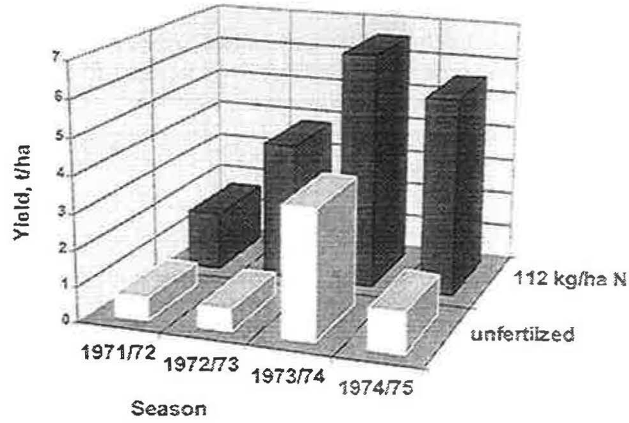

Figure 3. Yield of maize.

of composite maize varieties from the International Institute of Tropical Agriculture (IITA) grown under artificial infection by *S. asiatica* at Chitedze Research Station. Varieties with low *Striga* emergence, such as TZL Comp.1 C4, can help reduce the labour requirements for hand-pulling, and combine well with other approaches, such as nitrogen application or intercropping. Infestation by witchweed did not cause any yield loss due to other factors being non-limiting, such as deep ploughing and higher soil fertility. This shows the importance of good farming practices in managing the *Striga* problem. It is also generally reported that early maturing varieties escape damage. Previous work in Malawi showed that continuous use of a hybrid, in contrast to a synthetic variety resulted, in the long term, in higher grain yields (Figure 2). The important point is that these low support varieties would be useful in a combined control approach, in particular, where efforts are made to prevent emerged *Striga* from reproducing.

Animal manure, green manure and nitrogen application

The goal in the use of organic and inorganic fertilizers is to supply nitrogen to the crop to enhance yield in the current season. In addition, nitrogen fertilizers also suppress witchweed emergence. There are several mechanisms involved with the use of nitrogenous fertilizers. First, there are direct, injurious effects, especially with ammonium-based fertilizers. This is most effective at high rates. For example, 450 kg/ha N achieved all-season control in the USA. In Malawi, 122 kg/ha N gave 55% reduction in witchweed after 3 years and an increase in yield (Figure 3). Some of the effects of nitrogen include reduced stimulant production, reduced germination, retarded radicle growth, delayed emergence and flowering. The effects of nitrogen, therefore, help in reducing crop loss, reduce seed production and reduce the soil seed bank.

Table 3. Non-exhaustive list of trap crops for witchweeds of cereals

Groundnut	Dolichos (nkhungudzu)	*Tephrosia*
Soyabean	Mucuna (kalongonda)	Silver leaf
Cowpea	Cotton	Leucaena
Pigeonpea	Sesame	*Sesbania sesban*
Sunflower	Bambara nut	
Sunhemp	Guar bean	

Use of trap crops and legume intercropping

The mechanism involved with the use of trap crops is that *Striga* seeds are induced to germinate, but are unable to attach and parasitize and, therefore, die. Trap crops for *S. asiatica* and *S. aspera* are usually mostly legumes and some non-legumes (Table 3). One season trap cropping can give large reductions. However, two to three seasons may be required to bring levels really low (Figure 4). Maize and cowpea intercropping has been shown to suppress *Striga* emergence in the same season and in subsequent seasons in Malawi (Figure 4) and many reports from elsewhere. Table 4 presents first year results of a rotation experiment involving fertilized maize, and maize and pigeonpea and

Table 4. Effect of fertilizer application and *Tephrosia* and pigeonpea intercropping on grain yield and *Striga* emergence in 1998/99

Treatment*	Yield (kg/ha)	*Striga* no (m^{-2}) 56 DAP	*Striga* no (m^{-2}) 69 DAP
Maize, no fertilizer	862	79.6	87.9
Fertilized maize (69:21:0 + 4S)	2859	106.0	74.5
Maize no fertilizer + pigeonpea	635	119.8	56.3
Maize + (69:21:0 + 4S) + pigeonpea	2352	55.8	82.0
Maize, no fertilizer + *Tephrosia vogelli*	894	37.4	50.3
Mean	1406	78.8	66.8
P	<0.001	0.25	0.45
LSD (5%)	788	74	46
CV%	36	65	47

*At 12.5% moisture at Mpingu near Chitedze.
Source: After Kabambe and Gilbert (1999).

Table 5. 1996/97 season soyabean and groundnut yield in plots previously planted to maize differently fertilized in 1995/96

P_2O_5 applied to maize in 1995/96	1996/97 soyabean yield at 132 sites (kg/ha)	1996/97 groundnut yield at 39 sites (kg/ha)
1 (96:40:0)	1720	1870
3 (35:0:0)	1380	1510
4 (35:10:2)	1500	1670
5 (69:21:4)	1610	1730
6 (92:21:4)	1690	1890
2 (0-maize)	1170	1090

Source: After Malawi Maize Productivity Task Force, Action Group 1 (1998).

Tephrosia vogelii intercrops. Although *Tephrosia vogelii* was intercropped into maize after 2 weeks, it was capable of suppressing *Striga* emergence. This site had high levels of *Striga*, peaking at 119 plants/m^2. Fertilized maize (69:21:0 + 4S) yielded 2859 kg/ha. This result indicates that with fertilizer use, farmers may obtain some yield, but this yield is not the full potential yield for the hybrid. The purpose of rotation is to reduce witchweed incidence to levels where it can comfortably be managed by agronomic measures, such as low support varieties, intercropping and hand-pulling. For farmers not using fertilizer, sometimes a legume crop gives a better yield than the unfertilized crop, and it has higher nutritional and cash value than maize. This can be observed in Table 5 in which soyabean and groundnuts gave greater yields than continuous unfertilized maize. The legumes, however, benefited from some residual phosphorus added to maize in the previous season.

For legume rotations to be successful, however, Dashiel *et al.* (1999) showed that there is a need to examine cultivars for high *Striga* seed germination stimulation ability. The authors showed that *S. hermonthica* emergence on maize grown after soyabean with the best and second best *Striga* germination was only 50% of the worst. Maize yields were also higher in plots into which these high stimulant soyabean cultivars were grown.

These advantages were even higher with tolerant varieties. Differences in *Striga* germination by some lines and varieties of cowpea, pigeonpea and sunflower have been reported in Malawi (Kabambe, 1997) but no studies have been conducted to confirm similar work to that by Dashiel *et al.*, 1999). Also, Berner *et al.* (1996) studied the effect of soil pasteurization on *S. hermonthica* attachment to maize. They showed that *Striga* attachment in unpasteurized soils was reduced an average 47%, indicating that natural biotic suppression exists. Legume intercropping and residue incorporation would be one way to promote this aspect of control.

Integrated control

Generally all recommended husbandry practices cumulatively help to protect the crop from damage by witchweed or to reduce the seed bank. For example, because of the seed's preconditioning requirement, witchweed germination will only start at least 10 days from the first rains. Combined with nitrogen or manure application (which delays emergence), the crop can be given a head start if planted early. Also, by using improved varieties, there is better crop growth, canopy formation, shading and high relative humidity. Witchweed collapses under high relative humidity. Odhiambo and Ransom (1996) reported that the incorporation of maize residues reduced witchweed levels in the soil, particularly when stover yield was high. They attributed some of this effect to high levels of precursors of ethylene produced during the decomposition of stover.

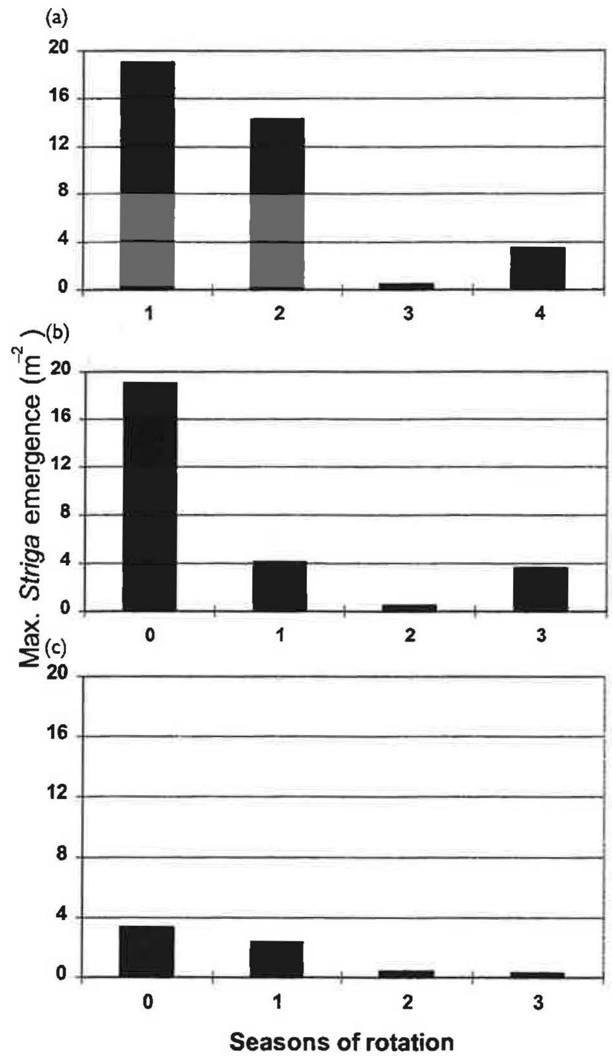

Figure 4. Effect of (a) continuous cropping; (b) rotation with groundnuts; and (c) maize/cowpea intercropping on maximum emergence of Striga *at Manjawila, 1993/94–1996/97.*

Ethylene has been successfully used to eradicate *Striga* in the USA by inducing *Striga* germination in the absence of a host (Eplee, 1975). Trap crops are more effective when managed properly because they can produce the required root system for effective suicidal witchweed seed germination, and produce more residues for green manure. Odhiambo and Ransom (1996) reported that cowpea was more effective as a trap crop for *S. asiatica* when it was fertilized than not fertilized. Even under witchweed infection, proper crop management can assist farmers to obtain higher yields. For example, in a farmer's field infected with *S. asiatica*, Kabambe *et al.* (2000) showed that application of basal fertilizers soon after emergence gave a significant yield increase compared to 2 weeks later.

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DISCUSSION

C. S. D. Mainjeni. How feasible is the use of chemicals in controlling witchweeds under smallholder conditions in Malawi considering problems such as technical knowledge, high costs and environmental pollution?

V. H. K. Most modern herbicides degrade quickly. The herbicide I consider feasible is applied to the seed so is straightforward to apply. In the long run, we need to realize that obtaining higher yields on smallholders' fields will require an investment.

M. M. Kayembe. Do these options apply to all cereals or maize only?

V. H. K. These options are for cereals in general.

J. Kapemba. Knowing that smallholder farmers are constrained by lack of income and land shortage, which options would you take as being practical and effective?

V. H. K. The farmer should use options that are practical for his/her situation.

C. Riches. How feasible do you think it will be for farmers to apply very low doses of herbicides as a seed dressing to small quantities of herbicide tolerant maize seed? How will the resistance genes be made available in the public domain?

V. H. K. There is interest in this question from a few countries in Africa. CIMMYT has asked its legal officer to follow it closely. We hope that smallholder seed multiplication groups develop so that they can be helped to treat seed.

On-farm trials of technologies for the management of *Striga asiatica* in Blantyre/Shire Highlands

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ABSTRACT

An on-farm trial was undertaken in three cropping seasons to develop management recommendations for witchweed (*Striga asiatica*) in maize for smallholder cropping systems in Blantyre/Shire Highlands Rural Development Project area of southern Malawi. Pest management strategies tested included the use of fertilizer, trap crops (soyabean, cowpea, *Tephrosia vogelii*) and green manures (*T. vogelii* and *Crotalaria ochroleuca*). In 1996/97, the trial was set up in fields where *Striga* had been reported as a problem, but *Striga* incidence proved to be too low. Additional fields with heavy *Striga* infestation were identified for the 1997/98 season. The trial was repeated on the same fields in 1998/99. Results in the 1997/98 and 1998/99 seasons demonstrated additional maize yields ranging from 300 to 1000 kg/ha with a single application of fertilizer at 50 kg N/ha, compared to no application. The presence of an intercrop of *Tephrosia vogelii* did not depress maize grain yields significantly when compared to having no intercrop in the absence of fertilizer application. The incorporation of *Tephrosia* biomass increased maize yield by about 30%. However, yields were slightly depressed when maize was grown with either cowpea or *Crotalaria* when these crops are grown in the first year with fertilizer applied to the maize crop. There was a significantly higher incidence of emerged *Striga* in fertilized plots compared to unfertilized plots, particularly when cowpea, *Crotalaria* and *Tephrosia* were not intercropped with maize.

INTRODUCTION

Witchweed (*Striga asiatica*) was identified as one of the major constraints to maize production in the Blantyre/Shire Highlands area during informal consultations with farmers (Orr *et al.*, 1997) as previously reported by the Soil Pests Project (Riches *et al.*, 1993). Based upon field surveys, Kroschel *et al.* (1996), estimated that the parasite is present in 75–87% of fields in Blantyre, Kasungu, Lilongwe and Liwonde districts, with a yield loss in infected stands of 10–59%, averaging 28%. *Striga asiatica* is parasitic on the host plant, and attacked plants often wilt leading to stunting and failure to produce seed. In heavily infested fields, hand-pulling did not improve maize yields though the seed bank might have been reduced (MoA, 1975). As reported by Riches *et al.* (1993), we found that the farmers are not fully aware of the plant's parasitic feeding system nor that the seed produced may remain viable for 15–20 years (Ritchie *et al.*, 1997).

Traditionally, control was by avoiding infested fields and long fallowing, some hand-pulling and use of crop rotation. With increasing land pressure, rotation and fallowing cannot be practised as maize cropping dominates, leading to low soil fertility which favours development of *Striga* infestation. Use of fertilizer and farmyard manure has been shown to have positive effects on the yields of *Striga*-infested maize as they provide adequate nutrients for growing maize plants (MoA, 1975; Kabambe *et al.*, 1997; Shaxson and Riches, 1998). The suppressive effect of nitrogen fertilizer on *Striga* seed emergence has been reported by other researchers (MoA, 1975; Kabambe *et al.*, 1997). Although a number of studies have shown that *Striga* infection generally declines with increasing nitrogen availability, the impact is partially dependent on the interaction between the formulation, timing and rate of nitrogen application and the severity of infestation (Mumera and Below, 1993). A number of detailed studies, reviewed by Pieterse (1996), have emphasized the inhibitory effect caused by ammonium nitrogen (but not by nitrate nitrogen) on *Striga* seed germination and radicle elongation and that both forms may reduce germination stimulant production by the host. For example, Igbinosa *et al.* (1996) have reported that increased concentrations of potassium nitrate, sodium nitrate, calcium nitrate and magnesium nitrate led to a significant increase in *S. hermonthica* shoot growth. On the other hand, increased concentrations of ammonium sulphate, ammonium phosphate, ammonium chloride and urea significantly reduced *Striga* shoot development. Ammonium nitrate did not suppress the shoot length and dry weight of *S. hermonthica* plants. However, it has also been reported that ammonium nitrate stimulates photosynthetic activity of both parasite, in this case *S. hermonthica*, and its sorghum host (Cechin and Press, 1993).

An increase in the ammonium nitrate supply can, therefore, result in a decrease in the inhibiting effect of *Striga* on its host's biomass accumulation. A number of factors, therefore, contribute to the impact of nitrogen application and inconsistent results are not unusual in the field due to environmental conditions influencing the concentration of nitrogen fertilizer in the soil, as well as the timing of the application in relation to the parasite's life cycle.

Trap cropping involves the use of a crop which stimulates *Striga* seed germination but does not support the *Striga* plants since no root attachment occurs. Many crops are reported to be potential trap crops including cotton, pigeonpea, sunflower, cowpea, groundnut, field pea, soyabean and pearl millet (Mkandawire, 1997).

In the Blantyre/Shire Highlands area, the size of landholding is small, about 0.4 ha/household and it is difficult to practise crop rotation. However, intercropping is common with maize as the main crop and legumes as companion crops. Trap cropping and green manuring could easily be tested in such a cropping system as these crops would be planted as additional intercrops. Thus our objective in this trial was to investigate the effects of trap crops and green manures with or without nitrogen fertilizer in a maize-based cropping system at *Striga*-infested sites.

MATERIALS AND METHODS

1997/98 and 1998/99 seasons

The 1996/97 season was characterized by a number of problems. Only one farmer had a heavy incidence of *Striga*, it was difficult for farmers to compare the treatments within the farm because of the complexity of the field layout, and unusually heavy rains led to little or no maize harvest. No data for the 1996/97 season are presented here. To overcome some of these difficulties, the experimental design was simplified and the number of plots increased to 8 plots/farm, including two control plots (see below). Several new fields which had shown heavy incidence of *Striga* in the 1996/97 season were chosen for the 1997/98 season. These fields were all in Matapwata Extension Planning Area (EPA), together with the single field where *Striga* had occurred heavily in the 1996/97 *Striga* trial in the same area. The specific position of the field was not the same for the plot adopted from the 1996/97 season. The bean intercrop was omitted to simplify the experiment and reduce data recording requirements. Plots were planted with maize (MH18) and pigeonpea (ICP 9145).

Two treatment factors were included in the 1997/98 trial. The use of fertilizer – factor (f) and the legume treatment

Farmer	Block No	Plot 1		Plot 2		Plot 3		Plot 4	
1	1	f_0t_1	f_1t_1	f_1t_0	f_0t_0	f_0t_2	f_1t_2	f_0t_0	f_1t_0
2	2	f_1t_2	f_0t_2	f_0t_0	f_1t_0	f_0t_1	f_1t_1	f_0t_0	f_1t_0
3A	3	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_0t_1	f_1t_1	f_0t_0	f_1t_0
3B	4	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0
4	5	f_1t_0	f_0t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1	f_1t_0	f_0t_0
5A	6	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0
5B	7	fF_0t_2	f_1t_2	f_0t_0	f_1t_0	f_1t_1	f_0t_1	f_0t_0	f_1t_0
6A	8	f_0t_0	f_1t_0	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1
6B	9	f_0t_0	f_1t_0	f_1t_2	f_0t_2	f_1t_1	f_0t_1	f_0t_0	f_1t_0
6C	10	f_0t_1	f_1t_1	f_1t_2	f_0t_2	f_1t_0	f_0t_0	f_0t_0	f_1t_0

Figure 1. Design layout for treatment factors in the 1997/98 Striga trial. f_0 = no fertilizer; f_1 = 50 kg N/ha dolloped fertilizer; t_0 = no Tephrosia or cowpea; t_1 = Tephrosia; t_2 = cowpea.

factor – factor (t). The fertilizer factor had two levels (fertilized or unfertilized) while the legume treatment factor had three levels in 1997/98 and four levels in 1998/99, i.e. no legume, the use of *Tephrosia*, the use of cowpea, and in 1998/99, the use of *Crotalaria*. *Tephrosia* and *Crotalaria* were used as green manure crops and cowpea as a trap crop. Treatments were:

Factor f:

f_0 = no fertilizer

f_1 = fertilizer applied

Factor t:

t_0 = no *Tephrosia* or cowpea

t_1 = *Tephrosia*

t_2 = cowpea

t_3 = *Crotalaria* (only in 1998/99)

To give farmers the opportunity to compare legume treatments, and at the same time observe fertilizer effects, the experiment was laid down, within each 'block' of area in a farm, as a split-unit design with 4 main plots (10.8 × 5.4 m), each divided into two to give a total of eight sub-plots (split-plots) of 5.4 m (6 planting stations) by 5.4 m (6 ridges). Among the four main plots, one had *Tephrosia*, and one had cowpea. In 1997/98, two plots were left as controls with no legume, but in 1998/99, one control plot was planted with *Crotalaria*.

The arrangement in 1997/98 left two of the eight sub-plots within each block with neither a fertilizer application, nor a legume treatment, thus increasing the chances of observing good *Striga* emergence in the absence of any inhibiting treatments. Of the sub-plot pair within each main plot, one was left unfertilized and the other was fertilized with CAN at 50 kg N/ha. In addition, each farmer had the same combination of treatments and could, therefore, compare his/her own field(s) with those of other farmers. Six farmers participated in the trial. Three of the farmers permitted the use of more than one field (block) in their farm for this researcher designed and managed experiment. The experimental layout and instances where extra replicates (blocks) occurred for some of the farmers are shown in Figure 1 for the 1997/98 season.

In each sub-plot, *Tephrosia* was planted at 4 seeds/station on one side of the ridge at a spacing of 45 cm between maize and pigeonpea plants. The pigeonpea was planted on the opposite ridge side to use the available space effectively. Cowpea was planted between maize and pigeonpea at 3 seeds/station planted on top of the ridge. *Crotalaria* seed was scattered along a line halfway up one side of the ridge only.

Measurements made with respect to *Striga* counts included the number of *Striga* plants that emerged, had flowered or were dead (before flowering). These data were collected at 2-week intervals from a quadrat of 0.9 × 0.9 m set up within each plot resulting in a quadrat size of 0.81 m^2. The net plot size for *Striga* sampling was, therefore, $(0.81/3) \times 9 = 2.43$ m^2. In analysing the data, however, this figure was rounded up to 2.6 m^2 to take account (approximately) of the actual net plot size for *Striga* sampling slightly circling the outside of the actual planting station.

Maize yield data were collected as total grain weight (kg) and usable grain, the difference between the two being the rotten grain weight. All grain yields were adjusted for moisture content and converted to kilogram per hectare before analysis. All statistical analyses were carried out using the software package Genstat Release 4.2, Fifth Edition.

The trial was repeated in 1998/99 using the same plots and adopting the same experimental design layout as in the previous year with two small changes. The additional control plot was planted to *Crotalaria*. The biomass of *Tephrosia* produced on the experimental plots in 1997/98 was low owing to poor growth, possibly caused by the early cessation of the rains and disease pressure. Accordingly, all the plots where *Tephrosia* was planted in 1997/98 received 2000 kg/ha of *Tephrosia* biomass (dry basis) gathered from a nearby estate to simulate the situation which would have existed if reasonable biomass had been produced on the plots in 1997/98.

RESULTS

Maize yields

Two yield responses were considered for analysis, i.e. total grain weight and usable grain weight. These responses were subjected to analysis of variance (ANOVA) procedures to investigate fertilizer effects, legume treatment effects and their interaction, allowing for possible variation between farmers, and interactions between farmer effects and the two treatment factors.

1997/98 cropping season

Data on maize yields were available from eight of the ten replicate blocks. The two missing blocks were for Farmer 5, who had harvested her maize crop early in the season because she was worried about theft. Only a total of 64 plots, therefore, were initially available for analysis. However, subsequent analysis revealed four outliers in the data. These came from two specific main plots where there appeared to have been data recording errors. Final analyses, therefore, were based on 60 observations.

The resulting analysis showed clear evidence that the application of fertilizer has an effect on actual grain weight and on usable grain weight ($P<0.001$). There was little evidence of a legume effect but strong evidence of a legume by fertilizer interaction ($P<0.01$).

The presence of interaction effects between legume and fertilizer and between farmer and fertilizer for actual grain weight can best be understood by examining the corresponding two-way tables of adjusted mean values in Tables 1 and 2.

Results in Table 1 show the absence of any adverse effects when *Tephrosia* is undersown in a maize field. This could be as a result of slow growth of *Tephrosia* in the earlier part of the season which increases after maize is harvested. However, the *Tephrosia* biomass too, was very small – about 120 kg/ha of dry leaf biomass and 1600 kg/ha of wet wood

Table 1. Adjusted means for maize yields by legume and fertilizer (1997/98)

	Grain weight (kg/ha)		Usable grain weight (kg/ha)	
Legume	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	675	1972	432	1342
Tephrosia	622	1868	424	1093
Cowpea	734	1509	433	734
SED (19 df)	136	237	130	240
P	0.718	0.100	0.997	0.024

biomass. Interplanting cowpea in maize gave significantly lower usable maize yields when fertilizer was applied (P=0.008). Cowpeas grew vigorously, probably competing with maize for nutrients and water which led to reduced usable maize yields in the fertilized plots. Cowpeas did not yield well as negligible grain yield (6 kg/ha) was obtained. Farmers felt that the cowpea variety used was unsuitable for the area although the seed was bought from the market in the same area. For the 1998/99 trial, farmers purchased suitable cowpea seed to be used in the trial.

Results in Table 2 demonstrate the benefits of fertilizer application in all farms. The significant interaction effect is due to the much larger increase in maize yields, following fertilizer application, in farms 4 and 6 compared to farms 1, 2 and 3. It is possible that the experimental blocks used in farms 4 and 6 had low soil nutrients and hence gave low yields (less than 400 kg/ha) on the unfertilized plots. This possibility was investigated by plotting the yields from unfertilized plots against each of the soil nutrients, i.e. pH, % organic matter, % nitrogen, phosphorus (ppm), magnesium (ppm), potassium (ppm), calcium (ppm) and zinc (ppm), in turn. In general, no clear pattern was observed. Magnesium showed a slight positive effect, i.e. yields increasing with increasing levels of magnesium, and calcium showed a slight negative effect. However, the availability of only five distinct soil measurements for this purpose made definitive conclusions difficult. Formal analyses, which look at the combined effect of soil nutrients on maize yields, were also not possible due to the limited number of soil measurements since they were recorded on a farm basis rather than on a plot basis.

Table 2. Adjusted means for maize yields by farmer and fertilizer

	Grain weight (kg/ha)	
Farmer	No fertilizer	Fertilizer applied
1	1114	2011
2	1048	1748
3	942	1586
4	387	1803
6	322	2016

Table 3. Adjusted means for maize yields by legume and fertilizer

	Grain weight (kg/ha)		Usable grain weight (kg/ha)	
Legume	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	838	1057	608	841
Tephrosia (incorporated as well as grown)	923	1379	755	1104
Cowpea	716	1015	552	802
Crotalaria	666	935	435	756
SED (12 df)	122.5	108.5	143.6	118.4
P	0.124	0.031	0.313	0.014

1998/99 cropping season

Maize yield responses analysed from data in the 1998/99 season again showed clear evidence that the application of fertilizer results in an increase in maize total grain weight and usable grain weight (P<0.001). There was some evidence that the presence of a legume had an effect (P=0.022 and P=0.045 for usable and total grain weights respectively), but the legume by fertilizer interaction was not significant. Nevertheless results presented in Table 3 show legume and fertilizer effects jointly, since further analysis revealed some differences across the legume treatment factor for fertilized plots. The results show little effect due to the legume treatment factor among non-fertilized plots. Fertilized plots, however, show strong evidence of an increase in maize yields when *Tephrosia* biomass is incorporated in the soil as well as *Tephrosia* being grown as an intercrop. Under these conditions, *Tephrosia* significantly increased maize yields by about 30% (P=0.016). On the other hand, both cowpea and *Crotalaria* intercrops reduced yields by about 5% and 10% respectively, but these reductions were not significant.

Table 4 shows the result of a strong farm by fertilizer interaction (P=0.001). There was no evidence of a farm by legume interaction (P=0.258 and P=0.408 for usable and total grain weights respectively). The application of fertilizer was beneficial to only two farmers. Maize yields were extremely low in the 1998/99 season, even where fertilizer was applied. This could be a result of the low fertility such that delaying the fertilizer application to 4 weeks after emer-

Table 4. Adjusted means for maize yields by farmer and fertilizer

	Grain weight (kg/ha)	
Farmer	No fertilizer	Fertilizer applied
1	445	602
2	1523	1935
3	622	705
4	143	344
5	1174	2175
6	720	776

Table 5. Number of plots with *Striga* (1997/98)

Legume	*Striga* emerged		*Striga* flowered		*Striga* dead without seeding		No. trial plots
	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied	
No legume	18 (90%)	20 (100%)	15 (75%)	19 (95%)	9 (45%)	17 (85%)	20
Tephrosia	9 (90%)	10 (100%)	9 (90%)	10 (100%)	6 (60%)	8 (80%)	10
Cowpea	9 (90%)	9 (90%)	9 (90%)	7 (70%)	8 (80%)	6 (60%)	10
Overall incidence	36 (90%)	39 (98%)	33 (83%)	36 (90%)	23 (58%)	31 (78%)	40

gence resulted in a maize crop that could not recover from earlier fertility inadequacy. Another reason could be that the incorporated crop and weed residues acted as competitors for the little nitrogen available in the soil such that applying the fertilizer later did not improve crop potential for low yield.

Striga counts

Three responses related to *Striga* incidence were analysed, namely the maximum, over six (five in 1998/99) sampling occasions of: (i) the total number of live *Striga* plants emerging from three quadrats (each 0.9 × 0.9 m); (ii) the number of *Striga* plants that flowered; (iii) the number of *Striga* plants dead without seeding.

1997/98 cropping season

With respect to data from the 1997/98 season, the number of plots with *Striga* are shown in Table 5. The incidence is quite high, particularly in fertilized plots.

ANOVA procedures, similar to those carried out for maize yields, were performed on each of these *Striga* count responses scaled up to per square metre basis. Subsequent residual analysis gave a clear indication that the variance homogeneity assumption of the ANOVA procedure was violated. The data, therefore, were transformed to logarithms and the analyses repeated.

The results showed little evidence of a legume effect on *Striga* emergence, flowering or deaths. Fertilizer effects were evident for emerged *Striga* plants (P=0.004) and for the numbers that flowered (P=0.022). There were more *Striga* plants where fertilizer was applied than where fertilizer was not applied. This is contrary to previous findings of some researchers who have reported fewer *Striga* plants emerging from fertilized plots than unfertilized ones (MoA, 1975; Kabambe, 1997; Khonga, 1996). Possible explanations for these conflicting results could include the amount and the way fertilizer was applied to the maize crop. Earlier reported work had fertilizer applied either as banding or deliberately mixed with the growing medium so that the *Striga* seed was in contact with the fertilizer, in which case *Striga* seed germination would have been affected. In the cultural management trial, 112 kg N/ha was applied (MoA, 1975). However, in this trial, fertilizer was applied in dollops on both sides of the maize station at 50 kg N/ha. This may have influenced the growth of the maize plant roots such that the root system grew more vigorously. This would have stimulated seed germination of *Striga* seed due to increased maize root development. Since fertilizer was dolloped, it would only inhibit *Striga* seed germination close to the dollop sites. Other possible reasons for this result could relate to the early timing of fertilizer application (at emergence), the fertilizer type (CAN), and the low background levels of fertility found on smallholder farms where the trial was sited (average % organic matter and % nitrogen of 1.06 and 0.05, respectively).

The analysis showed no evidence of any interaction effects between legume and fertilizer treatments. Adjusted mean counts on a log-scale appear in Table 6, while the means retransformed to the original scale of measurement (on a per square metre basis) are shown in Table 7.

Table 6. Mean log counts of emerged live and flowered *Striga* (1997/98)

Legume	log *Striga* emerged		log *Striga* flowered	
	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	1.83	2.81	1.64	2.09
Tephrosia (incorporated and grown)	2.05	2.18	1.15	1.49
Cowpea	2.51	2.57	1.74	1.86
SED	0.425	0.432	0.290	0.433
(df)	(15)	(17)	(21)	(16)
P	0.300	0.339	0.154	0.741

Table 7. Mean actual counts of emerged live and flowered *Striga* (1997/98)

Legume	*Striga* emerged		*Striga* flowered	
	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	6.2	16.7	5.1	8.1
Tephrosia (incorporated and grown)	7.8	8.9	3.2	4.4
Cowpea	12.3	13.0	5.7	6.4

Table 8. Predicted percentages of *Striga* plants dead without seeding (1997/98)

	Striga plants dead without seeding (%)	
Legume	**No fertilizer**	**Fertilizer applied**
No legume	18.1	22.4
Tephrosia	14.2	21.7
Cowpea	13.8	11.9
P	0.526	0.018

In general, plots with *Tephrosia* appeared to have lower *Striga* counts than plots with no legume or with cowpea. The exception was for *Striga* emergence without fertilizer where the mean for plots with no legume had lowest incidence.

Further analysis was carried out on the maximum number of *Striga* plants dead without seeding as a proportion of the maximum number that emerged at any sampling occasion. These data were analysed via logistic regression modelling procedures. The results for 1997/98 are shown in Table 8.

Here significant differences between the legumes were found only with respect to fertilized plots. This was largely the effect of fewer *Striga* plants killed under cowpea compared to plots without a legume and plots with *Tephrosia*. Since cowpeas are known to be a trap crop, the low death rate could be due to providing adequate shade for *Striga* plants to live to maturity. This refers to *Striga* plants that emerged due to maize root stimulation.

1998/99 cropping season

The same three responses related to *Striga* incidence were again analysed in the 1998/99 season. The number of plots with *Striga* are shown in Table 9. The incidence is highest for the number of emerged live *Striga* plants (about 80%), somewhat high for the number of *Striga* plants flowering (about 65%) and relatively low (30%) for *Striga* plants dead without seeding. Overall, incidence was found to be much lower than in the previous year. Casual field observation indicated that more *Striga* emerges where banking is absent or done superficially. Thus the differences between the two seasons in terms of *Striga* incidence could partly be attributed to banking since farmers did both the first weeding and banking in 1997/98 but these activities were undertaken by research labourers in 1998/99.

ANOVA procedures were carried out for the number of emerged *Striga* counts and the numbers that had flowered, using data converted to a per square metre basis. The analysis showed a clear indication (as in the previous year) that the variance homogeneity assumption of the ANOVA procedure was violated. The data, therefore, were transformed into logarithms and re-analysed. Neither legume effects, nor fertilizer effects were evident in this analysis, nor was there evidence of a legume by treatment interaction. Corresponding mean values of *Striga* counts (per square metre) across the legume treatment factor and for plots with and without fertilizer application are shown in Tables 10 and 11. Table 10 give results on the log-scale while Table 11 show results on the original scale of measurement.

Results of logistic regression analysis procedures applied to the maximum number of *Striga* plants dead without seeding as a proportion of the maximum number that emerged at any sampling occasion are shown in Table 12.

In the non-fertilized plots, significant differences were found between levels of the legume treatment factor with respect to the percentages of *Striga* plants dead without seeding. The results in Table 12 show that this effect is largely due to low percentages in the control plots and in the plots which have *Tephrosia* incorporated as well as grown. Fertilizer appears to have little effect when maize is grown with cowpea or *Tephrosia*. However, there is a considerable increase in the percentage of *Striga* plants dead without seeding when maize is grown by itself with the addition of fertilizer, or alongside *Crotalaria* (with or without fertilizer).

RELATIONSHIP BETWEEN MAIZE YIELDS AND *STRIGA* INCIDENCE

Data from the 3 years were combined to investigate whether there was any indication of a relationship between maize yields and *Striga* incidence. In 1996/97, only one farmer had a substantial incidence of *Striga* on her field. Out of five plots, however, yield data were available for only three plots. In the 1997/98 season, this farmer again had high levels of *Striga*, but unfortunately she harvested her maize yields early in the season, so it was not possible to include *Striga* on her fields from the 1997/98 season in studying the

Table 9. Number of plots with *Striga* (1998/99)

	Striga emerged		*Striga* flowered		*Striga* dead without seeding		
Legume	**No fertilizer**	**Fertilizer applied**	**No fertilizer**	**Fertilizer applied**	**No fertilizer**	**Fertilizer applied**	**No. trial plots**
No legume	9 (90%)	7 (70%)	6 (60%)	7 (70%)	2 (20%)	4 (40%)	10
Tephrosia	9 (90%)	7 (80%)	8 (80%)	5 (50%)	2 (20%)	2 (20%)	10
Cowpea	6 (60%)	8 (80%)	4 (40%)	5 (50%)	3 (30%)	2 (20%)	10
Crotalaria	9 (90%)	10 (100%)	8 (80%)	8 (80%)	5 (50%)	4 (40%)	10
Overall incidence	33 (83%)	32 (80%)	26 (65%)	25 (63%)	12 (30%)	12 (30%)	40

Table 10. Mean log counts (m^{-2}) of emerged live and flowered *Striga* (1998/99)

Legume	*Striga* emerged		*Striga* flowered	
	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	1.97	2.63	1.58	1.50
Tephrosia (incorporated and grown)	2.19	2.07	1.06	1.69
Cowpea	1.96	1.57	1.97	0.93
Crotalaria	2.71	2.16	1.74	1.61
SED	0.634	0.565	0.549	0.582
(df)	(20)	(19)	(13)	(13)
P	0.254	0.469	0.225	0.208

Table 11. Mean actual counts (m^{-2}) of emerged live and flowered *Striga* (1998/99)

Legume	*Striga* emerged		*Striga* flowered	
	No fertilizer	Fertilizer applied	No fertilizer	Fertilizer applied
No legume	7.2	13.9	4.9	4.5
Tephrosia (incorporated and grown)	8.9	7.9	2.9	5.4
Cowpea	7.1	4.8	7.2	2.5
Crotalaria	15.0	8.7	5.7	5.0

Table 12. Predicted percentages of *Striga* plants dead without seeding across fertilizer and legume effects

Legume	*Striga* plants dead without seeding (%)	
	No fertilizer	Fertilizer applied
No legume	2.9	15.6
Tephrosia (incorporated and grown)	4.2	7.4
Cowpea	10.0	8.2
Crotalaria	15.5	14.7
P	0.003	0.427

effect of *Striga* counts on maize yields. However, full information from the 1998/99 season was available for this combined analysis.

In 1996/97, the legumes grown were *Tephrosia* and soyabean. In 1997/98, *Tephrosia* and cowpea were grown, while in 1998/99, *Tephrosia*, cowpea and *Crotalaria* were grown. In combining the results across the three seasons, soyabean and *Crotalaria* were considered as additional trap crops. The use of *Tephrosia* also varied across the three seasons in that, in the 1998/99 season, it was grown alongside maize and was also incorporated into the soil. So these different forms of application were regarded as different forms of treatment.

Figures 2 and 3 show grain weight against number of live emerged *Striga* plants according to fertilizer and legume use for all three seasons. Figure 2 shows some indication of a higher *Striga* incidence in fertilized plots compared to non-fertilized plots. There is no clear difference in the pattern of the relationship under the different legumes. Formal statistical analysis of the data did not reveal any evidence that *Striga* counts had an influence on maize yields.

Although other research workers have found a strong negative relationship between the number of *Striga* plants emerging per maize station and maize grain yield per plant (MoA, 1975), there is little evidence of such an effect here. Of course sampling by these researchers was done on maize planting stations rather than in quadrats as used in the present

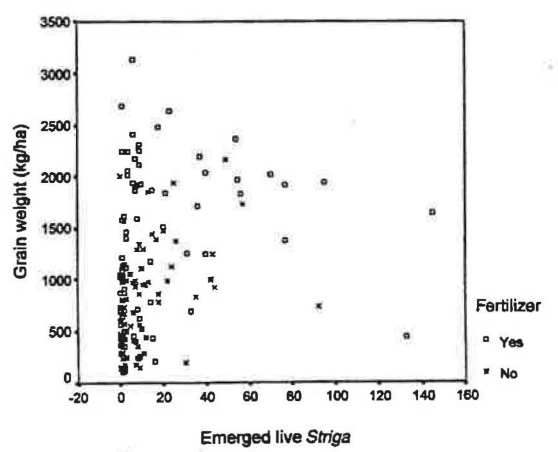

Figure 2. Grain weight versus emerged live Striga *counts by fertilizer application. Squares, fertilizer applied; crosses, no fertilizer.*

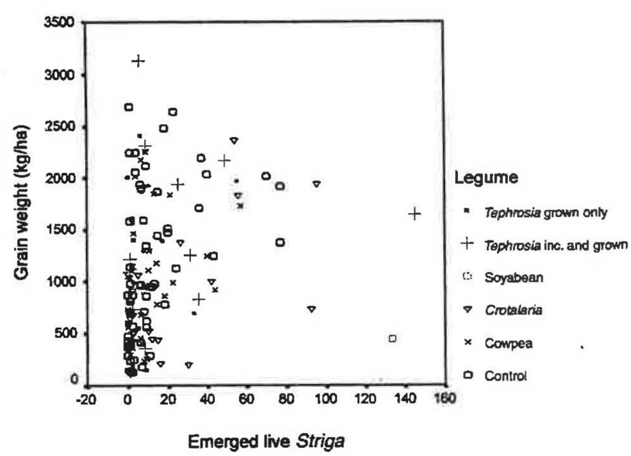

Figure 3. Grain weight versus emerged live Striga *counts by legume. Asterisk,* Tephrosia *grown only; cross,* Tephrosia *incubated and grown; square, soyabean; triangle,* Crotalaria*; cross, cowpea; circle, control.*

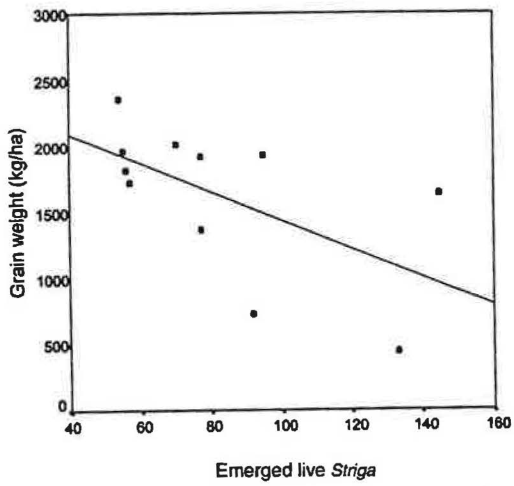

Figure 4. Grain weight versus emerged Striga *counts for plots with more than 50* Striga *plants.*

study. This may account for the lack of a clear relationship.

The graphs appear to indicate that *Striga* incidence has to be quite substantial before it can have any negative effects on maize yields. This was investigated by restricting the data to those plots where the number of emerged live *Striga* counts was more than 50. Only 11 plots had this high level of incidence. The data are plotted in Figure 4 along with a fitted line to describe the relationship. Regression analysis performed on this data explained 59% of the variation in maize grain yields, but there was no clear evidence of a significant dependence of yields declining with increased *Striga* counts (P=0.055) because of considerable variation in the data about the fitted line. However, given that other research has demonstrated a strong negative relationship, it is reasonable to look at the equation describing the yield versus *Striga* counts relationship, i.e.

$$Y = 2530.5 - 10.86X$$

where Y = grain yield; X = emerged live *Striga* plants.

From this relationship, we can postulate that under on-farm conditions, an increase of 10 *Striga* plants/m² can be expected to result in a decline of maize yields by 109 kg/ha.

Table 13. Adjusted means for maize yields by legume and fertilizer (two seasons)

	Usable grain weight (kg/ha)	
Legume factor	**No fertilizer**	**Fertilizer applied**
No legume	480	916
Cowpea	532	629
Crotalaria	385	569
Tephrosia (incorporated and grown)	704	917
Tephrosia (grown only)	411	1034
SED (12 df)	127	166
P	0.169	0.011

Combined analysis over two cropping seasons

Usable grain weight

Since the 1998/99 trial was conducted with the same farmers and using the same plots as used in 1997/98, the results from the two trials were combined into a single analysis to investigate the overall effect of the use of legumes/trap crops and the application of fertilizer. In this combined analysis, the use of *Tephrosia* alone in 1997/98 and the incorporation of *Tephrosia,* in addition to it being grown alongside maize as an intercrop, were distinguished as two separate treatments. Likewise *Crotalaria* was considered as an additional treatment in the 1998/99 season. The total number of treatments in the combined analysis was five, i.e. no legume (control), use of *Tephrosia* alone, *Tephrosia* incorporated and grown, cowpea and *Crotalaria.*

The analysis showed strong evidence of a farmer by year interaction (P<0.001) and some evidence of a year by fertilizer interaction (P=0.013). The latter was largely due to maize yields more than doubling with the application of fertilizer in 1997/98. In the 1998/99 season, only about a 30% increase in maize yields was observed with fertilizer application.

There was also a significant farmer by fertilizer interaction (as observed in both 1997/98 and 1998/99) and some evidence of a fertilizer by legume interaction (P=0.015). Legume differences, however, were found significant only when maize was fertilized. Table 13 summarizes the findings.

Emerged live Striga *plants*

Generalized linear modelling with a Poisson error structure was used to analyse the number of live *Striga* plants that emerged during the trial. This analysis again showed strong evidence of a farmer by year interaction (P<0.001) and some evidence of a year by fertilizer interaction (P=0.013). There was no evidence of a farmer by fertilizer interaction.

As expected there was also strong evidence of a fertilizer effect with more *Striga* plants emerging with the application of fertilizer. A legume by fertilizer interaction was also present (P=0.006). The results are summarized in Table 14.

It seems clear from results above that when fertilizer is applied with no legume, there is about a three-fold increase in the incidence of emerged live *Striga* plants. The effects of cowpea and *Crotalaria* on *Striga* emergence are little influenced by fertilizer application, but the presence of *Crotalaria* appears to increase *Striga* incidence to a greater extent than does the presence of cowpea. *Tephrosia* on the other hand, does increase *Striga* emergence under fertilizer application when grown by itself or when it is incorporated.

Table 14. Mean numbers of emerged live *Striga* plants

	Emerged live *Striga* plants/m²	
Legume factor	No fertilizer	Fertilizer applied
No legume	12.9	35.9
Cowpea	16.4	19.3
Crotalaria	25.6	28.2
Tephrosia (incorporated and grown)	15.8	22.6
Tephrosia (grown only)	9.6	16.9
P	0.062	0.004

DISCUSSION

Even after careful selection of trial plots in terms of *Striga* presence in the previous season, there was still a lot of variation in yields in control plots. Generally the organic matter and nitrogen levels in these fields were low: 1.06% and 0.05% respectively. The response of maize has also been variable, particularly in the 1998/99 season. *Tephrosia* and *Crotalaria* biomass production are not any better in these low soil fertility situations.

Though we have tested both *Tephrosia* and *Crotalaria* for two and one season(s), there is some positive contribution to increased production of the maize crop if we take into consideration the yields from unreplicated observations both in Matapwata and Mombezi EPAs. There are some concerns, particularly when nematodes and *Fusarium* wilt, are considered in a pigeonpea growing area. There is a need to continue collecting data related to these two aspects despite current data not showing any adverse relationship (Chanika *et al.*, p. 256). Both *Tephrosia* and *Crotalaria* are unsuitable for areas where tobacco is grown because the build-up nematodes may be enhanced.

Some preliminary work has shown that the root exudate from *Crotalaria juncea* caused 34% germination of the parasite seed compared to 57% for maize root exudate (C. R. Riches, personal communication). Thus seed bank depletion will be expected though this has to be balanced against maize yield loss from competition intercropping.

Use of cowpeas as a trap crop with current cowpea 'landraces' is limited because cowpeas are susceptible to *Alectra*. *Tephrosia* and *Crotalaria* do not support *Alectra* and *Tephrosia* has the advantage of being a potent source of *Alectra* germination stimulant (Mainjeni, 1999).

CONCLUSIONS

There was clear evidence that fertilizer application had a beneficial effect on maize yields. The increase in yield ranged from 300 to 1000 kg/ha with a single application of 50 kg N/ha.

Tephrosia did not affect the maize crop adversely and an increase in maize yield of about 30% was realized when *Tephrosia* biomass was incorporated. However, both cowpeas and *Crotalaria* depressed yield when intercropped in the first year though this was not statistically significant at P=0.05.

Striga incidence increased when fertilizer was applied to maize and a yield loss of 109 kg was estimated when 10 *Striga* plants were present on 1 m². Despite this weak negative relationship between *Striga* incidence and some loss of maize grain yield, farmers would benefit from the application of inorganic fertilizer in their *Striga*-infested fields. They should also consider increasing soil fertility status by growing and incorporating *Tephrosia* biomass as it increases yields by a further 30%.

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DISCUSSION

B. Kamanga. In the second year of your trial the maize yields were higher than in the first year. However, many reports have shown a decline in yields in the second season especially with green manure incorporation. How do you explain the increase in yield? Is it due to the effect the *Tephrosia* has on the control of soil fertility?

C. S. M. C. The increase in nitrogen (and other nutrients) from the decomposition of *Tephrosia* residues does influence yields.

J. Mapemba. Presentations have shown that fertilizer application increases emergence of *Striga* while another says that fertilizer application reduces weeds. Incorporation of *Tephrosia* increases numbers of whitegrubs, but reduces *Striga* emergence. How do we reconcile these statements?

C. S. M. C. A trade-off between the different IPM strategies is required. If farmers are losing by incorporating *Tephrosia* as it increases whitegrubs rather increasing yields as a green manure then no incorporation is necessary and *vice versa*.

A. Chirembo. Why did you delay or doubt when to apply fertilizer. I thought there was a recommendation about when to apply fertilizers.

C. S. M. C. Current fertilizer recommendation is for one application at emergence. However, this is for depleted soils. You could delay application until a later date if soils are fertile.

B. Mwale. Is there any benefit in incorporating *Tephrosia* if it increases emergence of *Striga*?

C. S. M. C. I think yes. But what is important is that the farmer also combines this with other strategies, such as hand-weeding to control *Striga*. We need an integrated approach to pest management.

C. Pelekani. Since incorporating *Tephrosia* into the soil is proving to be important for increasing soil fertility, but it is also known to increase the build-up of root-knot nematode, care should be taken before adopting the technology in areas of high-value crops, such as tobacco, which are very susceptible to the nematode, as yields of these crops will be affected drastically.

Resistance to the yellow witchweed, *Alectra vogelii* Benth., in common bean and cowpea in Malawi

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ABSTRACT

The yellow witchweed, *Alectra vogelii* Benth., has been observed as a widespread problem on a number of grain legume crops in Malawi, including common bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* (L.) Walp). In glasshouse pot experiments at Long Ashton Research Station in the UK, 12 selections of common bean were screened for their susceptibility to *A. vogelii* from Malawi. Two showed low susceptibility to the parasite. This variation in susceptibility indicates the possibility for selecting resistant common bean lines in future. Nine selections of cowpea from Malawi, Botswana and West Africa were exposed to a seed sample of *A. vogelii* collected from Malawi. There was variation in susceptibility. All the germplasm from Malawi and West Africa was highly susceptible. The cowpea B359, ex-Botswana, was completely free of any parasite attachment and provides a source of resistance for the breeding of resistant cultivars for Malawi. The resistance observed in B359 and Mkhalira was not associated with low parasite germination stimulant production and further work is needed to characterize the mechanism(s) of resistance in these lines.

INTRODUCTION

Alectra vogelii distribution and host range

Alectra vogelii Benth. (the yellow witchweed) is an important root hemiparasite occurring in Africa on a wide range of cultivated grain legumes. The distribution of *A. vogelii* extends from Transvaal in South Africa and Swaziland in the south through central Africa to Burkina Faso, Kenya and Ethiopia in the east, across Western Africa to Mali (Philcox, 1990; Riches *et al.*, 1992; Riches and Parker, 1995). In Malawi, *A. vogelii* has been observed in several districts namely Thyolo, Mulanje, Chiradzulu, Blantyre, Zomba, Mangochi in the south and Dedza, Lilongwe and Nkhotakota in the centre.

Alectra vogelii is a major parasite of cowpea [*Vigna unguiculata* (L.) Walp.] and groundnut (*Arachis hypogaea* L.). Bambara nut [*Vigna subterranea* (L.) Verdc.] and mungbean [*Vigna radiata* (L.) R. Wickzek] are attacked in parts of east and southern Africa (Riches, 1989, 1994). It has occasionally been reported on chickpea (*Cicer arietinum*), soyabean [*Glycine max* (L.) Merr.], runner bean and many legume fodder crops, including *Dolichos lablab*, siratro and velvet beans [*Mucuna pruriens* (L.) DC] (Parker and Riches, 1993).

Various studies, including those of the Farming Systems Integrated Pest Management (FSIPM) Project, which conducts on-farm research to identify pest management strategies for smallholder farmers in southern Malawi, have observed *A. vogelii* in fields of common beans in the Blantyre/Shire Highlands (Riches and Shaxson, 1993; Ritchie *et al.*, 1997). At Thuchila, infestation of *A. vogelii* on groundnut was observed on more than 50% of the crop plants (Riches and Shaxson, 1993). In a transect survey in fields within the Blantyre/Shire Highlands, Ritchie *et al.* (1997) observed that infestation of *A. vogelii* in common bean fields was about 50%. Mainjeni (1999) observed that cowpea was the main host of *A. vogelii* at Sandama, Khonjeni, Matapwata, Bvumbwe (all in Thyolo), Lidala (Chiradzulu) and Mwatakata in Mangochi. In Mchinji, one of the main groundnut growing areas, a heavy infestation of *Alectra* was also observed on groundnuts (V. Kabambe, October 1999, personal communication). Triangular transect surveys of *Striga* incidence in Kayenda Village (Chiradzulu North Extension Planning Area (EPA)) (Chanika and Koloko, 1998) and in Magomero Village (Matapwata EPA) (Ritchie and Koloko, 1998) during March 1998 indicated that 52% and 11%, respectively, of all fields had *Alectra* present. When only fields with bean, cowpea or groundnut were counted, the incidence of infestation was 100% at Kayenda and 62.5% at Magomero (J. M. Ritchie, November 1999, personal communication).

Effects of *A. vogelii* on leguminous crops

Root parasitic weeds cause most damage to the host while they are still below ground (Parker and Riches, 1993). Not all the parasite stems emerge and this makes their control difficult. In south-east Botswana, yield losses due to *A. vogelii* can reach 80–100% on heavily infested fields of cowpea (Riches, 1989). Beck (1987) reports yield reductions in bambara of up to 49% and groundnut damage in the eastern Transvaal of South Africa. Salako (1984) found up to 34–39% pod yield loss in one infested groundnut plant.

Botha (1948) states that *A. vogelii* is primarily a water parasite and it mainly robs the host plant of its water supply. Plants affected by *A. vogelii* show signs of wilting and yellowing prior to *Alectra* emergence. Mugabe (1983) found that onset of flowering of the host was delayed, and there was a reduced number of flowers and pods, as well as reduced yield of dry pods and cowpea seed, even under well-watered conditions. It was also noted that infested plants were smaller than uninfested ones, and that decrease in cowpea yield corresponded to an increase in *A. vogelii* dry matter.

Economic importance of leguminous crops

Cowpea is a widely adapted, stress-tolerant grain legume, vegetable and fodder crop grown on about 7 million ha in warm to hot regions of Africa, Asia and America (Ehlers and Hall, 1997). In Malawi, cowpea is produced on 78 000 ha of land with an average yield of 679 kg/ha (Ortiz, 1998). Common bean is grown throughout the country in Mzimba and Rumphi North as well as Chitipa. In the central region, common bean is grown in Ntchisi, Ntcheu, Salima and Dowa West, whilst in the southern region it is grown in Thyolo, Mulanje and Namwera Rural Development Project (RDP) (Ferguson *et al.*, 1992). Both crops are important sources of protein in the diet of rural households in Malawi and it is, therefore, important to provide farmers with options for the control of production constraints including *A. vogelii.*

Options for the control of *A. vogelii*

Cultural and mechanical methods

Alectra vogelii has a similar life cycle to that of *Striga* and reflects a high dependence of the parasite on the host plant during both the early developmental stages and after the parasite has developed its own green leaves (Dorr *et al.*, 1977; Dawoud, 1995). A number of control measures used for *Striga* may be applicable to *A. vogelii*, although limitations exist in most methods used to control both parasites.

Parker and Riches (1993) and Eplee and Norris (1995) recommend the removal of parasitic weeds, including *A. vogelii* shoots, by hand-pulling, cultivation, hoeing and rogueing before the parasitic plants can set seed back into the soil. These techniques are, however, labour intensive.

Rotation of host crops with non-host or false hosts (trap crops) can prevent reproduction of *Alectra* by inducing suicidal germination of the seeds of the parasite. Visser and Beck (1989) observed that guar (*Cyamopsis tetragonoloba* (L.) Taub.) was not parasitized by *A. vogelii* although guar produced a germination stimulant that made the parasite germinate. Only long rotation programmes can give a significant reduction in parasitic weeds. Robinson and Dowler (1966) found that 3 years of planting the trap crop garden pea in the USA was required to achieve a significant reduction in *S. asiatica* infestation. In Malawi, land pressure is an increasing problem because of the growing population in the country. It is, therefore, difficult for farmers to take land out of production while a trap crop is grown.

Tarfa *et al.* (1999) found that application of nitrogen at both 20 and 40 kg/ha reduced and delayed *Alectra* emergence in all the varieties of soyabean they evaluated. Mugabe (1983) found that phosphorus treatment had a suppressive effect on the early growth of *A. vogelii.* Unfortunately, farmers in Malawi are generally unable to afford the high cost of fertilizers (Shaxson and Riches, 1998).

Chemical and biological control

Although a number of soil-applied germination stimulant analogues and herbicides have been shown to control *Striga* species, including *S. gesnerioides* on cowpea (Parker and Riches, 1993; Berner *et al.*, 1994), problems of costs of development in relation to a relatively limited commercial market and the difficulty of introducing chemical control for a minor crop of resource-poor smallholders limits their potential use. No biological control agents have been reported for *A. vogelii.*

Host plant resistance

The introduction of acceptable varieties which are resistant to *A. vogelii* is a more applicable control strategy on fields of resource-poor farmers. The International Institute of Tropical Agriculture (IITA) in collaboration with Semi-Arid Food Grain Research and Development (SAFGRAD), Burkina Faso, Institute of Agricultural Research (IAR), Samaru, Nigeria, and Long Ashton Research Institute, UK, initiated work on screening and breeding for resistance to *Striga* and *Alectra* in 1981 (IITA, 1984; Sing and Emechebe, 1991). Systematic screening has revealed cowpea varieties which are resistant. B301 a landrace from Botswana initially identified by Riches (1987) is resistant to both *Striga* and *Alectra* in West Africa. Cowpea IT82D-849 an improved breeding line from IITA (Sing and Emechebe, 1991) is resistant to *Striga* but highly susceptible to *Alectra.*

In southern Africa, in a series of pot trials in both glasshouse and the field, resistant cowpea lines were selected from the seed of landrace plants collected from good yielding cowpea plants in *Alectra*-infested stands on farmers fields. Riches (1987) reported that cowpea accessions B301 and B359 provided promising sources of resistance to *A. vogelii* collected in Botswana. Riches *et al.* (1992) subsequently reported that B359 was also resistant to a sample of the parasite collected from central Malawi. No work appears in the literature on the possible resistance to *A. vogelii* in common bean.

A glasshouse study was, therefore, undertaken to investigate the possibility of selecting resistance in common bean by pot screening, to confirm the resistance of cowpea B359 to *A. vogelii* from the Blantyre/Shire Highlands and to examine the susceptibility of some cowpea lines recently developed by IITA for southern Africa.

MATERIALS AND METHODS

To screen for differences in susceptibility to the parasite in varieties of beans and cowpea, pot trials were established in the tropical glasshouse at Long Ashton Research Station, UK.

Table 1. Mean number of emerged *A. vogelii,* unemerged parasite attachments, height of the five tallest parasite stems and parasite dry weight on 12 selections of common bean 85 days after planting

Variety	No. emerged parasites*	Mean height (cm) of five tallest stems'	No. unemerged parasite attachments*	Total dry weight (g)'
Nagaga	7.53 (56.70)	2.68 (14.59)	6.37 (40.58)	0.76 (2.13)
Chimbamba	4.70 (22.09)	2.75 (15.64)	3.45 (11.90)	0.96 (2.13)
G22501	4.66 (21.72)	2.88 (17.81)	3.33 (11.09)	0.79 (2.60)
Mlama 127	4.56 (20.79)	2.04 (7.69)	3.32 (11.02)	−1.29 (0.27)
Nanyati	4.51 (20.34)	2.15 (8.58)	4.53 (20.52)	−0.15 (0.06)
Kaulesi	3.83 (14.67)	2.38 (10.80)	2.12 (4.49)	0.55 (1.72)
PAD-3	3.64 (13.25)	2.95 (19.11)	3.36 (11.29)	0.02 (1.01)
Kalima	3.34 (11.16)	2.34 (10.38)	4.18 (17.47)	−1.00 (0.36)
Napilira	3.15 (9.92)	2.22 (9.21)	2.31 (5.34)	−1.34 (0.25)
Nasalen	2.93 (8.58)	1.52 (4.57)	4.50 (20.25)	−1.28 (0.27)
Kambidzi	1.51 (2.28)	1.58 (4.85)	0.93 (0.86)	−2.65 (0.06)
Mkhalira	0.53 (0.28)	2.03 (7.61)	0.68 (0.46)	−3.76 (0.01)
SED	1.534 (43 df)	0.609 (33 df)	1.523 (43 df)	1.317 (43 df)
LSD (P=0.05)	3.09	1.24 NS	3.07	2.66

*Means calculated from data transformed to square root x.
'Means calculated from data transformed to log x.
'Means calculated from data transformed to log (x+0.01).
Means in brackets are back-transformed data.

Approximately 450 viable *A. vogelii* seeds were mixed with each pot of soil. The soil used had 6 parts shredded/sterilized loam, 4 parts peat, 2 parts cornish grit and 1.7 parts perlite. Osmocote 3–4 month fertilizer was mixed in the soil at 3.3 g/l. This contained 15% nitrogen, 11% phosphoric acid, 13% potassium oxide and 2% magnesium oxide. Trace elements 0.02% boron, 0.05% copper, 0.4% iron, 0.06% manganese, 0.02% molybdenum and 0.015% zinc were available in this fertilizer. Host plants were thinned to 1 plant/ 12.5 cm diameter pot after emergence (after 7 days from planting). Heating and ventilation were controlled at 25 °C day and night. A photoperiod of 16 h was maintained during the first 2 weeks after planting.

Twelve varieties of bean from Malawi (Table 1) and nine varieties of cowpea (Table 2) from southern Africa (Botswana and Malawi) and West Africa (IITA) were screened in two experiments. In both experiments, *Alectra* emergence was counted every 3 days up to 85 days (12 weeks after planting). Total number of emerged *Alectra* per cultivar entry at harvest was recorded. The height of the five tallest *Alectra* plants was measured in each replicate pot following the procedure used by Riches (1987, 1989) and Hamilton (1990). All the emerged *Alectra* were cut at soil level, placed in paper bags and put in an oven at 80 °C for a 24-h period to obtain the dry weight of the parasite. In the bean screening experiment, all roots were washed free of soil to record unemerged *Alectra* parasites at the termination of the experiment.

Table 2. Mean number of days to emergence of *A. vogelii* on nine cowpea selections

Cowpea variety	Days to first parasite emergence	Days to 50% parasite emergence
B301	63.76	66.74
IT90K-59	52.20	64.74
IT90K-76	42.20	62.48
Ex-Bvumbwe	42.00	56.30
Ex-Sandama	37.40	50.20
Sudan-1	37.20	57.62
Ex-Magomero	36.80	56.94
IT82E-16	34.80	52.66
B359*	None	None
SED	2.940	2.387
df	(27)	(27)
LSD (P=0.05)	6.03	4.90

*Excluded from analysis.

The germination stimulant assay involved surface sterilizing the *Alectra* seed in 70% ethanol for 5 min and rinsing three times in distilled water (Visser *et al.*, 1977). The seed was then pipetted on glass microfibre paper (GFA) in petri dishes, sealed in clear plastic bags and black plastic bags. The dishes were then put in an incubator at 30 °C for 10 days to precondition the seed (Botha, 1948). To induce germination of *A. vogelii* after the preconditioning period, root exudates from 5-day-old bean, Nagaga and Mkhalira as well as cowpea ex Bvumbwe, B301 and B359, 7-day-old garden pea (*Pisum sativa*), chickpea (*Cicer arietinum*), fish bean (*Tephrosia vogelii*), were added to each replicate dish, incubated at 30 °C for 48 h and the germinated seeds were assessed using the stereomicroscope (x10 magnification). A logit transformation of data on germination stimulant assay was conducted when angular transformation showed non-homogeneity of variance data.

Data was analysed using the GENSTAT statistical package for a one-way analysis of variance (ANOVA) for pots placed in randomized blocks. Preliminary tests using residual fitted plots revealed the need to transform the data in all except

Table 3. Mean number of emerged *A. vogelii*, height of five tallest stems and dry weight of the parasite on nine selections of cowpea at 85 days after planting

Cowpea variety	No. emerged parasites*	Mean height (cm) of five tallest stems'	Total dry weight (g)'
Sudan-1	8.67 (75.17)	3.56 (35.16)	2.18 (8.84)
Ex-Bvumbwe	8.47 (71.74)	3.38 (29.37)	1.79 (5.98)
Ex-Magomero	8.32 (69.22)	3.55 (34.81)	1.89 (6.61)
Ex-Sandama	8.14 (66.26)	3.48 (32.46)	1.86 (6.41)
IT82E-16	7.60 (57.76)	3.52 (33.78)	1.97 (7.16)
IT90K-76	6.65 (44.22)	3.19 (24.29)	1.62 (5.04)
IT90K-59	4.52 (20.43)	2.65 (14.15)	0.59 (1.79)
B301	1.90 (3.61)	1.23 (3.42)	−2.87 (0.05)
B359§	0	0	0
SED	0.956 (28 df)	0.181 (27 df)	0.402 (28 df)
LSD(P=0.05)	1.96	0.37	0.82

*Means calculated from data transformed to square root *x*.
'Means calculated from data transformed to log *x*.
'Means calculated from data transformed to log (*x*+0.01).
§Excluded from analysis. Numbers in brackets are back-transformed data.

the 'days to emergence' variable. The ANOVA was carried out on the square root of the total number of emerged and unemerged parasites. A log transformation was used on the height of the five tallest *Alectra* plants per pot treatment whilst log (dry weight + 0.01) was used for the dry weight.

RESULTS

Bean variety screening

Significant differences (P=0.012) were observed between the numbers of *A. vogelii* emerged on beans at the termination of the experiment. The cultivar Nagaga supported a significantly higher number of emerged parasites at harvest than seven other varieties namely, Kalima, Kambidzi, Kaulesi, Mkhalira, Napilira, Nasalen and PAD-3 (Table I). Nagaga also had significantly higher numbers of unemerged attachments than four other varieties of beans namely, Kaulesi, Napilira, Kambidzi and Mkhalira.

The number of emerged parasites on Mkhalira was significantly lower (P=0.05) (Table 1) than seven other bean varieties namely, Nagaga, Chimbamba, G22501, Mlama 127, Nanyati, Kaulesi and PAD-3 whilst unemerged attachments were significantly lower than other bean varieties. Kambidzi also supported low numbers of emerged *Alectra* compared to Nagaga, Chimbamba and G22501. Unemerged parasite attachments on bean line Kambidzi were significantly lower than four other varieties of beans namely, Nagaga, Nanyati, Nasalen and Kalima.

The total dry weight of *Alectra* shoots at harvest was significantly different between the varieties (P=0.016). Chimbamba, Nagaga and G22501 had significantly higher dry weight of *Alectra* shoots (P=0.05) compared to Kambidzi and Mkhalira (Table 1). Mkhalira and Kambidzi gave the lowest dry weights of *Alectra* (0.01 and 0.06 g/pot, respectively).

The low number of emerged *Alectra* parasite attachments and total dry weight supported by bean varieties Mkhalira and Kambidzi indicates the possible resistance of these two cultivars to *A. vogelii*.

Cowpea variety screening

Significant differences (P=<0.001) in days to emergence of the first parasite were observed between the cowpea varieties. Emergence of *Alectra* on cowpea B301 at approximately 64 days after planting (Table 2) was significantly later than on seven other varieties (P=0.05), namely IT90K-59, IT90K-76, ex-Bvumbwe, ex-Sandama, Sudan-1, ex-Magomero and IT82E-16. First emergence of *Alectra* on the local varieties ex-Bvumbwe, ex-Sandama, ex-Magomero, Sudan-1 and IT82E-16 (35–42 days) was significantly faster than on the IITA variety IT90K-59 (52 days).

Emergence of 50% of the *Alectra* on cowpea ex-Sandama by 50 days was significantly earlier (P=0.05) than on six other varieties namely ex-Magomero, ex-Bvumbwe, IT90K-76, IT90K-59, B301 and Sudan-1 (Table 2). On variety B301, 50% emergence of *Alectra* at 67 days was significantly later (P=0.05) than on five other varieties but was similar to IT90K-59 and IT90K-76.

Significant differences (P=<0.001) were observed between cowpea selections in the number of emerged *A. vogelii* shoots at harvest, the mean height of five tallest stems and parasite dry weight (Table 3). For variety B301, the mean number of *Alectra* shoots and the mean height of the parasite stems was significantly lower (P=0.05) than the other selections (Table 3). Similarly, the dry weight of *Alectra* shoots in B301 was significantly lower (P=0.05) than the rest of the cowpeas (Table 3). The landrace B359 from Botswana did not support any *Alectra* emergence and no parasite attachments were observed on the roots of B359 after washing off the soil. The cowpea IT90K-59 supported sig-

Table 4. Effect of the root exudates from a range of legume crops on *A. vogelii* seed germination

	Exudate concentration (%)*		
Host crop	**100**	**10**	**1**
Cowpea (ex-Bvumbwe)	1.83 (86.17)	1.54 (82.28)	-0.002 (49.95)
B359	1.55 (82.47)	1.67 (84.22)	1.07 (74.43)
B301	1.50 (81.82)	1.37 (79.79)	1.40 (80.23)
Mkhalira	0.08 (52.03)	–1.89 (13.17)	–4.18 (1.50)
Nagaga	–0.34 (41.54)	–1.82 (13.97)	–3.78 (2.23)
Tephrosia	0.85 (69.99)	–	–
Garden pea	–0.97 (27.58)	–	–
Chickpea	–4	–	–
SED	0.3182 (51 df)		
LSD (*P*=0.05)	0.64		

*Mean percentage germination calculated from logit(*x*).
Assay used *A. vogelii* ex-cowpea except for Mkhalira and Nagaga which were assayed against parasite ex-bean.
–, Not tested. Numbers in brackets back-transformed data.

nificantly lower numbers of parasites (*P*=0.05) than six of the other varieties, ex-Sandama, ex-Bvumbwe, ex-Magomero, Sudan-1, IT90K-76 and IT82E-16 (Table 3). The number of *Alectra* shoots and mean height of the parasites supported by the local cowpea cultivars from Malawi, ex-Sandama, ex-Bvumbwe, ex-Magomero and Sudan-1 were similar.

Germination stimulant production

Root exudates of all the crop species and cultivars tested stimulated the germination of *A. vogelii*, but significant differences (*P*=<0.001) in the germination percentage of *A. vogelii* seeds were noted between the sources of root exudate tested. Root exudate from cowpea ex-Bvumbwe induced a higher level of germination (*P*=0.05) than bean, pea or the green manure legume, *Tephrosia vogelii* (Table 4).

Comparisons made between the parasite-susceptible cowpea ex-Bvumbwe and resistant cowpea B359 did not show any significant differences in percentage *A. vogelii* germination. Similarly, there were no differences between susceptible Nagaga and resistant type Mkhalira at all the concentrations tested (Table 4). The results suggest that the low susceptibility of common bean line Mkhalira and the complete resistance of cowpea B359 are not due to a lower level of germination stimulant in the root exudates, compared to susceptible lines.

Tephrosia vogelii which did not support any *A. vogelii* in the pot trials (data not given) triggered a high germination percentage (70%) of *Alectra* seed in the root exudate assay (Table 4). This may suggest that *T. vogelii* can be used as a trap crop in the control of *A. vogelii*.

DISCUSSION

The susceptibility of the bean and cowpea varieties to *A. vogelii* from Malawi has been put into four categories (Table 5) namely resistant (R), slightly susceptible (+), moderately susceptible (++) and highly susceptible (+++) based on Riches (1988, 1989) plus observations on pot trials in this study. The results on common bean Mkhalira and cowpea B359 suggest that both are resistant to *A. vogelii* from Malawi, whilst common bean Kambidzi and cowpea B301 are both slightly susceptible to the *A. vogelii* ex-common bean

Table 5. Susceptibility of common bean and cowpea on *A. vogelii* from Malawi

Crop	**Level of susceptibility***
Common bean	
Nagaga	+++
G22501	+++
Chimbamba	+++
Mlama 127	+++
Nanyati	+++
Kaulesi	+++
Kalima	++
PAD-3	++
Napilira	++
Nasalen	++
Kambidzi	+
Mkhalira	R
Cowpea	
Sudan 1	+++
Ex-Bvumbwe	+++
Ex-Magomero	+++
Ex-Sandama	+++
IT82E-16	+++
IT90K-76	+++
IT90K-59	++
B301	+
B359	R

*Scale based on Riches (1988, 1989) plus observations on pot trials and *in vitro* growth results (Mainjeni, 1999).
R, Resistant, not more than 1 parasite stem/plant.
+, Slightly susceptible, 2–5 parasites/plant.
++, Moderately susceptible, 5–15 parasites/plant.
+++, Highly susceptible, ≥15 parasites/plant.

and cowpea host respectively, from Malawi.

The results, the first of their kind on common bean, suggest that a number of bean lines with resistance to *A. vogelii* may be found in the future. More bean lines should be screened in order to produce a high number of resistant germplasm lines. Riches (1988) observed that only 12 accessions of cowpea remained parasite-free when 358 accessions were studied. In another related study Riches (1987) found that out of 201 accessions screened only four remained parasite-free. The local varieties which have been shown to be highly susceptible to *Alectra* in this study are favoured in all the three regions of Malawi. Chimbamba, Kaulesi and Nanyati are grown throughout the country in large quantities and are fast cooking beans (Ferguson *et al.*, 1992). In addition, Chimbamba produces the best dry beans throughout the country. Therefore, if Mkhalira and Kambidzi are confirmed in further studies to be resistant in the field, the resistant traits or genes from these could be transferred into the susceptible but favoured varieties through plant breeding.

All lines of cowpea from Malawi and West Africa were shown to be highly susceptible to *A. vogelii*. These included cowpea lines ex-Bvumbwe, ex-Magomero, ex-Sandama as well as Sudan-I seeds. IT90K-59 and IT90K-76 whose parents include B301 and IT82E-16, from IITA, Nigeria, were also susceptible. Cowpea B301 showed low susceptibility whilst B359 was completely free from attack of this parasite. The results are comparable to those found by Hamilton (1990) and Riches *et al.* (1992) who reported that cowpea B359 was resistant to *A. vogelii* from Malawi but that the same sample attacked B301. Riches *et al.* (1992) reported that cowpea B359 was found free from *Alectra* infestation in a wide range of locations. The resistance of B359 should now be verified in the field as it would appear to be a useful source of resistance to *A. vogelli* for introduction into improved cowpea varieties for use by smallholders in Malawi. B359 is a late maturing indeterminate variety, which does not flower until 70 days after planting. It is, therefore, unsuitable for immediate release to farmers (Riches, 1988).

The results in this study show that resistance of bean Mkhalira and cowpea B359 found in pot trials and the *in vitro* growth system is not due to low parasite germination stimulant production. Riches (1989) and Hamilton (1990) found similar results on cowpea B359 and reached similar conclusions. Some preliminary work (data not presented) suggests that following germination *A. vogelii* fails to develop on the roots of B359. Few germinated seedlings became attached and developed on Mkhalira. Further studies in this area are needed to characterize the mechanisms of resistance found in these lines.

It is interesting to note that *T. vogelii* is a potent stimulator of the germination of *A. vogelii*. Pot trials have demonstrated, however, that it is not a host of the parasite (data not presented). This species, which has been shown to be a potentially useful green manure in the Blantyre/Shire Highlands would, therefore, appear to be a useful trap crop for the reduction of *A. vogelii* infestations.

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DISCUSSION

A. J. Sutherland. How was the research design influenced by information from farmers for this and earlier research reported on *Striga*? In Kenya, farmer strategies on *A. vogelii* related more to soil fertility management, such as intercropping indeterminate cowpeas with maize on manured land, or manuring a sole crop of cowpea. They knew the effect of *A. vogelii* and were worried when it spread from cowpea to the bean crop.

C. E. D. M. According to Dr Ritchie, the problems of *Striga* and consequently *Alectra* were identified by farmers, for example, they ranked *Striga* as the second most important pest of maize. Also, when transect surveys in the area were conducted, *A. vogelii* was noted on more than 50% of the *Phaseolus vulgaris* crop.

I. Hoeschle-Zeledon. Are the root exudates of the different species and varieties chemically the same or are they very different?

C. E. D. M. We do not know whether the root exudates of different species and varieties are chemically different. This is probably one of the areas requiring further research.

A. Chirembo. Previously we noted that screening of beans under intercropping showed different varieties performing well as opposed to the those that the breeder favoured. Now with *Alectra*, it is noted that most of the breeders' recommended varieties do not do well. Are the bean breeders aware of these new findings? If the breeder is aware what is the future for releasing varieties, should all these problems, *Striga, Alectra*, intercropping, be considered in breeding programmes?

C. E. D. M. It is important that the breeder be informed of these problems so that he can take all of them into consideration when developing new varieties. I intend to give a copy of my research work to the breeders.

C. T. Kisyombe. It is exciting news that the two released common bean varieties Kambidzi and Mkhalira are resistant to *Alectra vogelii*. However, I would like to mention that there are many more problems that we are working on in common bean, such as identifying and developing varieties for high yield potential, adaptability, tolerance to low soil fertility, reaction to diseases, acceptable grain characteristics and cookability. Therefore, although there are more problems we can work on like *Alectra*, we have to prioritize our work and so minor problems may not be addressed by the Bean Improvement Programme. However, the *A. vogelii* problem has been noted and we hope when resources become available it will be addressed for the benefit of bean farmers in those parts of the country where it is recorded as serious by the FSIPM Project.

6. Enhancing Smallholder Management of Soil Fertility

KEYNOTE ADDRESS

A review of potential legumes for integrated nutrient management in maize-based systems in Malawi with emphasis on pigeonpea

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ABSTRACT

The use of green manures for increasing soil fertility in Malawi was first documented more than 70 years ago. This paper summarizes some of the results from potential food and non-food legumes which have been screened for improving soil fertility and maize yields through integrated nutrient management under Malawi conditions. The attributes of a legume considered to have potential in increasing soil fertility include chemical quality characteristics of the plant, ease of nutrient release from the green manure or crop residues, the amount of shoot biomass produced by the plant, the potential of the plant in fixing nitrogen and the competitive nature of the plant under intercropping systems. Among the potential legumes identified for increasing soil fertility in Malawi, pigeonpea (*Cajanus cajan*), *Tephrosia vogelii*, *Mucuna pruriens* and *Crotalaria juncea* seem to have been researched extensively in comparison to other legumes. This review mainly concentrated on those legumes with the potential to increase soil fertility in smallholder farmers' fields where the application of inorganic fertilizers is minimal because farmers cannot afford to purchase them.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L) is one of the most versatile pulses in maize intercropping systems in Malawi. Among grain legumes, it ranks sixth in total world production (Sharma and Green, 1975). However, Rachie (1973) expressed the view that pigeonpea yields are grossly underestimated because the crop is seldom grown in pure stands on a large scale and the produce is almost entirely consumed locally. In Malawi, pigeonpea is widely grown in the southern parts of the country intercropped with maize and is grown sparsely in other parts of the northern and central regions of the country. The maize/pigeonpea intercropping system is attracting increased interest in Malawi because research results have shown that the yield of a long maturing pigeonpea variety (ICP9145) when intercropped with maize does not affect the yield of maize (Sakala, 1994). The slow growth of pigeonpea in the early stages offers little competition to the companion maize crop. After maize is harvested, the pigeonpea grows at a faster rate well into the dry season using residual soil moisture. It has also been reported that cereals grown after pigeonpea gave significantly greater yields than after other legumes (Kumar Rao *et al.*, 1983; MacColl, 1989). In addition to other legumes, such as *Tephrosia*, pigeonpea has been identified as having potential for improving soil fertility under smallholder agriculture. Pigeonpea produces larger amounts of biomass, mainly senesced leaves which have an average of 2% nitrogen. It produces leaf biomass of over 5 t/ha. This leaf biomass satisfies the requirement of an equivalent of 30 kg N/ha, which is the minimum level of fertilizer nitrogen equivalence for green manure to be effective. This is also true for *Tephrosia vogelii* and *Mucuna pruriens*. In Malawi, several planting systems of pigeonpea exist. These include planting every year between maize hills or at the foot of the ridge. Ratooning, which is regeneration of pigeonpea which has been cut back, is also widely practised (Sakala, 1994).

Pigeonpea in Malawi is grown mainly as food and as a cash crop. Of late it has been realized that pigeonpea has great potential for increasing soil fertility (Sakala, 1998). The attributes which give it a high potential for improving soil fertility include: complementarity of the pigeonpea in the maize/ pigeonpea intercropping system, plant residue quality, nitrogen-fixation and the ability of the pigeonpea litter to contribute residual nitrogen to the following crop.

RESULTS AND DISCUSSION

Complementarity

There is minimal competition between maize and pigeonpea in an intercropping system. The onset of competition between the intercrops can be delayed by judicious choice of relative planting dates, plant population density and crop geometry. These factors permit a planned sharing of natural resources and manipulation of competitiveness to suit targeted yields (Midmore, 1993). Alteration of relative plant-

Table 1. Effect of pigeonpea planting on maize and pigeonpea yield (t/ha) across six sites for three seasons

	Yield (t/ha)	
Pigeonpea planting time	**Maize**	**Pigeonpea**
Same as maize	3.0	0.69
2 weeks after maize	3.0	0.68
4 weeks after maize	3.1	0.47

ing dates, besides modifying the relative periods of complementarity and competition, also influences the extent to which plants of associated crops achieve their yield potential (Table 1). When maize and pigeonpea are intercropped, maize yield is not affected by the planting time of the pigeonpea in the maize, but pigeonpea yields are reduced if planted 4 weeks after maize has been planted. These results are similar to cassava/pigeonpea intercropping. In cassava/pigeonpea intercropping, a 40% reduction in pigeonpea yield was caused by a 5-week delay in planting in Australia compared with pigeonpea planted at the same time as the cassava (Cenpukdee and Fakai, 1992). Intercropping of two crops which reach physiological maturity at different times would be more advantageous if the late maturing crop is able to recover quickly from any growth reduction caused by the harvesting of the early maturing crop.

A large time interval with favourable conditions between the harvesting of the component crops ensures that the late maturing crop has sufficient time to develop a complete canopy and root system to capture as much as possible of the remaining resources, such as photosynthetically active radiation (Tasty *et al.*, 1988). Pigeonpea intercropped with sorghum recovered well after the early maturing sorghum was harvested, and its dry matter production during pod filling was similar to that in sole cropping (Natarajan and Willey, 1980). In Malawi, long duration pigeonpea yields are better when intercropped with maize within the same ridge compared with maize and pigeonpea planted on alternate ridges because pigeonpea grows well into the dry season after maize has been harvested and is able to compensate for its growth (Table 2).

Table 2. Effect of spatial arrangement on maize and pigeonpea yield (t/ha) across six sites for three seasons

	Yield (t/ha)	
Spatial arrangement	**Maize**	**Pigeonpea**
Same row	3.6	1.1
Alternate row	2.6	0.8

Plant litter quality

Litter quality, climate and the nature and abundance of the decomposing organisms are major factors which influence litter decay (Heal *et al.*, 1997; Swift *et al.*, 1979). Climate is the dominant factor in areas subject to unfavourable weather conditions, whereas litter quality is more important in favourable conditions (Couteaux and Bottner, 1995; Handayanto *et al.*, 1997; Cadisch and Giller, 1997a, b). Of the above factors, litter quality can easily be managed by farmers (Palm *et al.*, 1997). Nitrogen release from crop residues can be slow or rapid depending on the quality of residues. Pigeonpea leaves are of better quality than maize residues, hence are more useful for soil fertility improvement (Table 3). Nitrogen contents of maize and senesced pigeonpea leaves are 0.70 % and 1.86 %, respectively. The C:N ratio of maize stover is three times that of senesced pigeonpea leaves. The behaviour of nutrient release for *Tephrosia* is similar to that of pigeonpea since they both have similar litter quality. The maize and *Tephrosia* relay intercropping system is promising. Gilbert (1997) indicated an average of 50 kg N/ha can be realized from *Tephrosia* when relay intercropped within 3 weeks of maize planting. *Tephrosia* seed is either broadcast along the ridge or systematically interplanted.

Both slow and rapid release of nutrients from organic fertilizers can have positive or negative effects on nitrogen management in the soil. Rapid release enhances early nitrogen uptake by the crop but may lead to nitrogen loss through leaching if crop demand is less than the amount of nitrogen being released. Slow release would guarantee a continuous supply of nitrogen during most of the growing period of the crop although if the amount of nitrogen released is small its contribution to crop growth may not significantly boost crop performance. Palm and Sanchez (1991) in a decomposition experiment with 10 tropical legumes and rice straw indicated that polyphenolic content may play a more important role in influencing mineralization patterns for leguminous leaves than % nitrogen or lignin-to-nitrogen ratio. However, Fox *et al.* (1990) suggested that the lignin + polyphenol:N ratio appeared to be a good predictor of nitrogen mineralization rates of incorporated legumes. Pigeonpea litter has been characterized as fast nitrogen release (green pigeonpea leaves) and slow release (senesced leaves). Both types of residues are far better at releasing nitrogen than the maize residues which are present in greater amounts (Figure 1). For normal crop production, senesced leaves are more important because the farmer still has the grain legume yield and soil fertility improvement is a bonus.

Table 3. Chemical composition of crop residues of maize and pigeonpea

Residue type	**N (%)**	**Lignin (%)**	**TEP (%)**	**C : N**
Maize stover	0.7	5.7	0.5	60
Senesced pigeonpea leaves	1.9	15.7	1.3	24
Green pigeonpea leaves	3.2	12.8	1.5	14
Mixture of maize stover and senesced pigeonpea leaves	1.3	8.5	0.7	33

TEP = total extractable polyphenols.

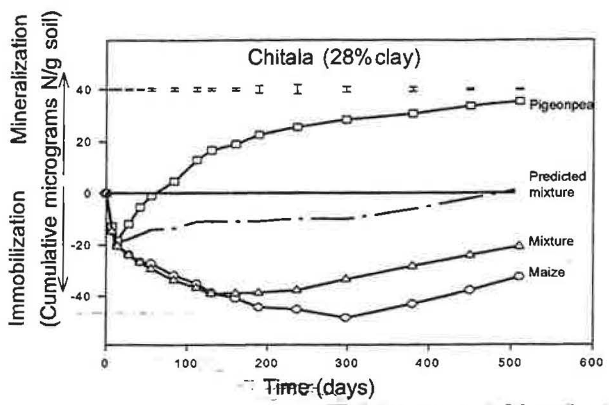

Figure 1. Cumulative net nitrogen mineralization from senesced pigeonpea leaves, maize residues, mixture of maize residues and senesced pigeonpea leaves and the predicted mean of sole senesced pigeonpea leaves and maize residues.

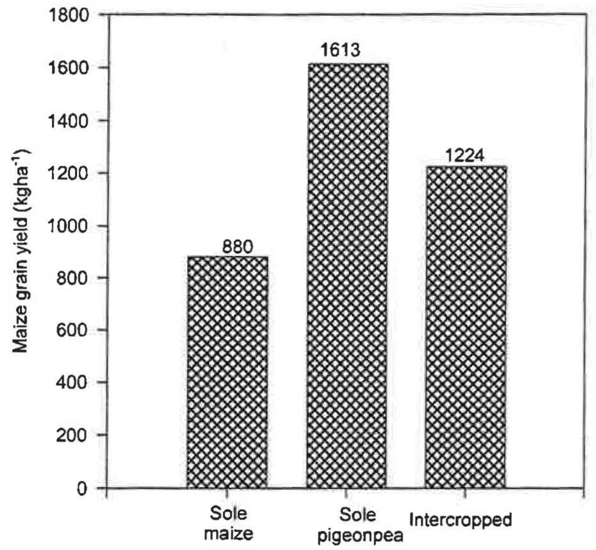

Figure 2. Mean unfertilized maize yields for two sites, Chitedze and Lisasadzi, following sole maize, sole pigeonpea and intercropped maize and pigeonpea.

Nitrogen-fixation

The quantity of nitrogen fixed by a legume may be affected by a number of factors: crop species, plant morphology, legume density in a mixture, agronomic management, and competitive ability of the component crops (Ofori *et al.*, 1987). Legumes of indeterminate growth are more efficient in terms of nitrogen-fixation than determinate types because they have a higher yield potential. Pigeonpea and *Tephrosia* have most of the above attributes which makes them efficient in nitrogen-fixation. Although determinate legumes such as soyabean, groundnut and cowpea fix nitrogen, their potential under intercropping is limited. For example, Eaglesham *et al.* (1982) found that in a growing season, soyabean fixed more nitrogen than cowpea, but soyabean used a greater amount of fixed nitrogen to produce seed. In a similar study, when groundnut was intercropped with pearl millet, maize or sorghum, nodulation and nitrogen-fixation were reduced (Nambiar *et al.*, 1983). This effect was ascribed to the shading of the groundnut plant by the cereal and the consequent decrease in photosynthesis of the legume canopy resulted in lower dry matter production in intercropped groundnut than in sole groundnut.

In a sorghum/soyabean intercrop system, a tall sorghum variety reduced soyabean yield by 75% and nitrogen-fixation at the early pod fill stage by 99%. Again shading by the cereal was found to be the main factor in reducing both seed yield and nitrogen-fixation potential of the companion legume (Wahua and Miller, 1978). Pigeonpea is a nodulating legume and there is evidence of both low and high nitrogen-fixation abilities. Kumar Rao *et al.* (1987) reported that pigeonpea could fix up to 69 kg N/ha/season which amounted to 52% of the total nitrogen uptake. Fixation was greater with long maturing duration types, though there were differences within the maturity group. Again Sakala (2000) reported 51–84% of nitrogen fixed by pigeonpea in sole and intercrops. Actual amounts of nitrogen fixed ranged from 35 kg N/ha to 138 kg N/ha with high amounts of nitrogen fixed coming from sole pigeonpea plots although intercropped pigeonpea had the largest percentage of nitrogen fixed (Table 4).

Residual nitrogen from legumes

Residual nitrogen can help to reduce the amount of inorganic fertilizer applied to the subsequent crop. Legumes

Table 4. Amounts of N fixation using natural abundance method and N derived from soil and fertilizer by pigeonpea at Chitedze site in 1996/97 season

Cropping system	N fixed (%)	Shoot biomass	Total N biomass (kg/ha)	N fixed	N soil + fertilizer
20 kg N/ha sole crop	51	14774	266	136	130
Intercrop	82	10961	198	163	35
80 kg N/ha sole crop	48	14767	265	127	138
Intercrop	51	7101	129	63	65
Mean	69	11900	215	131	77
SEM		4893	88	51	54

Table 5. Maize yield following a 2-year improved fallow

	Yield (t/ha)	
Species	**Grain**	**Stover**
Sesbania sesban	5.5	7.0
Tephrosia vogelii	2.8	5.3
Sesbania macrantha	3.0	4.2
Pigeonpea	2.8	4.5

Source: After Kwesiga and Coe (1994).

which have a high capacity for fixing atmospheric nitrogen can be beneficial if most of the crop residues are returned to the soil. If residues are not returned to the soil the nitrogen which is fixed by the legumes is lost from the system. Kumar Rao *et al.* (1983) found that medium duration pigeonpea alone had a large residual effect on maize, increasing grain yield by 57% and total dry matter by 32% compared with corresponding values after fallow. Intercropped pigeonpea had little residual effect. Sakala (1998) also found similar increased maize yields after 1-year sole pigeonpea crop followed by intercropped pigeonpea while the smallest maize yields were found in plots where there had been continuous maize for two successive years (Figure 2). In a similar experiment, Singh (1983) found that if wheat followed a legume intercrop, its growth, yield attributes and nitrogen uptake were increased, but Singh and Verma (1985) reported that pigeonpea UPAS 120 (an early maturing genotype) had a negligible effect on yields of the following wheat compared with fallow. When pigeonpea was compared with *Tephrosia candida* and natural bush fallow to improve the productivity of an acid soil, *Tephrosia candida* and pigeonpea increased surface soil organic carbon and total nitrogen content over the natural bush, but only *Tephrosia candida* plots produced improved maize grain and stover yield when all the plots were planted to sole maize in the second year (Gichuru, 1991). In an early short-term rotation experiment in Malawi, maize, groundnut and tobacco yielded better in rotation than when grown for a second successive year on the same land and green manures gave the largest crop increase (Brown, 1958). Although green manures gave the highest yield increases, it was noted at that time that green manures suffered the handicap of occupying the land unproductively for a year and required a considerable amount of labour when being ploughed into the soil.

Short-term improved fallows have been widely investigated. Kwesiga *et al.* (1994) reported maize yield after four species were used as improved fallows (Table 5). Out of the four species, maize yields were highest following *Sesbania sesban* while the other three species *Tephrosia vogelii*, *S. macrantha* and pigeonpea had similar maize yields.

CONCLUSION

Pigeonpea and *Tephrosia* have all the attributes for increasing soil fertility in Malawi. These species, however, must managed appropriately if the full potential benefits are to be realized.

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DISCUSSION

B. Mwale. Is there a recommendation as to when farmers should incorporate pigeonpea biomass because from your graph of nitrogen release by number of days it takes almost 100 days to release 20 kg N? How can farmers maximize the benefits of nitrogen release from pigeonpea residues?

W. D. S. Normally pigeonpea leaves are incorporated in a continuous process because senescing leaves continue to drop throughout the season and this helps the maize in the second year. Farmers can benefit from nitrogen release from pigeonpea by growing maize and pigeonpea under intercropping year after year. The alternative is to grow pigeonpea as short improved fallow which will give higher benefits but this system is only suitable for farmers with large land holdings.

R. B. Jones. Pigeonpea is mainly grown in southern Malawi. This region is known for its winter rainfall. It does not appear to perform as well in central and northern regions. Has any work been done to look at soil moisture use under pigeonpea?

W. D. S. No work has been done on this, but it is a good topic for further study.

D. Coyne. To what extent is it known how much pests and diseases (particularly soil borne) contribute to the overall issue of loss of soil fertility (or yield decline)?

W. D. S. Very little information is available and this area needs further study.

Best-bet green manures for smallholder maize-based cropping systems of Malawi

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ABSTRACT

Green manures such as *Tephrosia vogelii*, *Mucuna pruriens* and *Crotalaria juncea* have long been identified as promising leguminous species for Malawi. The recent increase in the fertilizer:maize price ratio means that there is increasing interest in leguminous options for improving soil fertility, which has led to a re-examining of green manure systems. However, leguminous cropping systems must compare favourably to existing farming practices in terms of food security and economic returns before they will be adopted by smallholder farmers. Two cropping systems emerge as 'best bets': *Tephrosia vogelii* undersown early to maize, and *Mucuna pruriens*-maize rotations. Constraints to the widespread adoption of these cropping systems (e.g. *Tephrosia* performance in areas of low rainfall, and *Mucuna* toxicity), and future leguminous research needs are discussed.

INTRODUCTION

Malawi is only 118 000 km^2 in area, yet it has a diverse agro-ecology; 55 natural regions have been identified (Benson, 1997a). The altitude in agriculturally active areas varies from 0 m to 2000 m above sea level, and average annual precipitation from 600 mm to 2000 mm. The varied terrain and soil type in hilly areas make blanket soil fertility recommendations impractical, and much recent research and extension effort has gone into using geographical information systems (GIS) to generate area-specific recommendations for fertilizer application and organic matter technologies. The precipitation pattern is unimodal, with 4–6 months of rain followed by 6–8 months of drought, with high variability which is typical of southern Africa and makes rainfed agriculture a risky proposition. The long drought period also makes double-cropping or relay-cropping of legumes into maize problematic, as dry season growth and survival is poor for most species.

Like many African countries, Malawi's burgeoning population (population density is 93 people/km^2) has led to decreased fallow periods, stagnant food production and declining food production per capita. However, Malawi is unique in its dependence on maize as its staple food crop. Over 90% of total cultivated area is planted to maize, mostly by resource-poor smallholders. Malawi consumes over 150 kg maize per capita annually, which constitutes more than two-thirds of their caloric consumption – the largest per capita consumption in the world (Smale and Heisey, 1997). There is evidence of declining soil organic matter levels as soils are continuously cropped to maize. Mean organic carbon levels in three regions declined 10–31% over a 20-year period (Blackie *et al.*, 1998). Fertilizer and maize price subsidies were recently removed, which has led to a rising fertilizer:maize price ratio, and has made fertilizer use on maize largely uneconomic for market sale (Benson, 1997b).

The socio-economic and biophysical context of Malawi have important connotations for leguminous cropping systems. Farmers are searching for ways to ameliorate soil fertility that reduce the need for fertilizers, which provides an important entry point for legumes. However, the intense land pressure means that any leguminous system must be competitive with continuous maize on the basis of calorie production per hectare and economic net benefits. Legumes that can satisfy economic and caloric criteria while still improving soil fertility are termed 'best-bet' systems because they are most likely to be adopted by smallholder maize producers. This paper will describe the best-bet green manure legumes identified so far, and discuss future research needs for leguminous cropping systems in southern Africa.

INTERCROPS OF *TEPHROSIA VOGELII* WITH MAIZE

In unimodal rainfall systems, the growing season is constrained by moisture availability. Maize/legume intercropping systems must minimize competition for water, light and soil nutrients to be sustainable. Successful leguminous intercrops such as pigeonpea and fish bean (*Tephrosia vogelii*) both exhibit a temporal complementarity or resource use with maize. These crops grow slowly early in the season and use residual moisture to remain green in the dry season. Thus they are not competitive with maize, but still produce enough biomass to have a significant effect on soil fertility.

The intercropping of green manures has only been recently studied. However, the promotion of green manures in Malawi is certainly not new. Davy (1925) names *Tephrosia* *vogelii, Crotalaria juncea* and *Mucuna pruriens* as promising green manure species for Nyasaland. *Crotalaria* and *Mucuna* were found to have a greater positive effect on maize yields than other green manures used extensively in crop rotations in Zimbabwe through the 1950s (Rattray and Ellis, 1952). *Crotalaria* and *Mucuna* have been shown to be excellent nitrogen-fixers in a wide range of environments (Bowen *et al.*, 1988; Buckles *et al.*, 1998; MacColl, 1990; Yost *et al.*, 1985). *Tephrosia* has been less well-researched. It is renowned as a fish poison and has the advantage of being unpalatable to livestock and remaining green in the dry season.

Green manures have the potential to accumulate up to 250 kg N/ha/year (Giller and Wilson, 1991; Peoples and Herridge, 1990), resulting in subsequent cereal yield increases of 600–4100 kg/ha (Peoples and Herridge, 1990). However, these figures are for sole-cropped green manure species. The nitrogen benefits and best management options for green manure species undersown to maize in Malawi have not yet been elucidated. The key question for undersown green manure technology is whether it can increase maize yields using agronomic management practices that fit into existing farming systems.

Gilbert (1997) tested four green manure species *(Tephrosia vogelii, Mucuna pruriens, Lablab purpureus* and *Crotalaria juncea*) intercropped to maize at two times (2 weeks after planting T1, 6 weeks after planting T2) and at two seeding rates (low S1, high S2). He found that the different growth habits of the green manures have practical implications for their management. While *Mucuna* produces copious biomass, it tends to smother the maize. While *Tephrosia* is not competitive with maize due to its slow growth rate, neither does it outcompete weeds, and thus it is difficult to keep weed-free. The growth habit of *Crotalaria* appears ideal for maize intercropping, since it is not overly competitive with the maize, yet also shades out weeds. However its short growth duration (to maximum green biomass) makes incorporation problematic since it reaches this stage while the maize is still growing. The early incorporation of *Crotalaria* also means there is a higher potential for loss of nitrogen due to mineralization and leaching under late-season rainfall.

When the biomass data for *Tephrosia* was compared across sites, it became clear that biomass production was linearly correlated to precipitation received. Average T1 biomass at Bvumbwe (1760 mm rainfall) was 2.9 times that at Chitedze (787 mm). The response curve for the T1 undersowing date had a steeper slope (4.35 kg biomass/mm) than T2 (1.86 kg/mm), indicating the response to rainfall was muted in the T2 treatments, most likely due to increased competition with maize when undersown later. The correlation between rainfall and biomass did not hold for the other species tested. Biotic factors such as vine rot reduced *Mucuna* biomass in high rainfall environments, whereas the short growth duration of *Crotalaria* did not enable it to make full use of the available soil moisture.

When averaged across all sites, *Tephrosia* undersown at T1 produced the greatest biomass of the treatments tested. This was achieved with <20% drop in maize yield associated with these treatments, due to the temporal complementarity in the growth habits of *Tephrosia* and maize. In contrast, *Mucuna*, especially sown early, can be overly competitive with maize due to its aggressive climbing growth habit, reducing maize yield up to 60%. *Mucuna* thus may be better suited to rotational systems.

Tephrosia seed was broadcast at 20–40 kg/ha in that study. The Malawi Agroforestry Extension project (MAFE) in 1997 initiated a demonstration at 200 sites aimed at promoting the undersowing of *Tephrosia* into maize. The MAFE cropping system demonstrated was slightly different in that the *Tephrosia* seed was not broadcast, it was planted at the same time as maize in two stations in between maize hills. In addition, the original design called for 1 year of *Tephrosia* fallow following the first year of intercropping, after which the 2-year-old *Tephrosia* plants would be harvested for seed and fuelwood. Preliminary data from the first season from 195 sites indicated that *Tephrosia* was not competitive with maize: average maize yield in the maize/*Tephrosia* intercrop was only 3% lower than the control (MAFE/PROSCARP, 1997). MAFE earlier reported an average *Tephrosia* biomass of 3–5 t/ ha leaves and 7–10 t/ha wood at the end of the second season. The direct-seeded system has the advantage of earlier planting, lower seeding rate, and easier weeding than the broadcast seed method. However, the fallow year is a disadvantage in areas of land scarcity. It now appears that a fallow year may not be necessary in areas of high precipitation if *Tephrosia* is planted early (T. Bunderson, personal communication).

Tephrosia, like pigeonpea, is well-suited to intercropping systems due to its temporal complementarity of resource use with maize. Unlike pigeonpea, it does not have a food value, and thus other benefits, such as fuelwood and soil fertility, will have to be much larger than pigeonpea for it to be attractive to small-scale farmers. It may be best-suited for land that is so degraded that it is about to be abandoned by farmers.

MUCUNA–MAIZE SYSTEMS

Mucuna pruriens (velvet bean) has been widely promoted as a superior green manure crop in Honduras, Benin and elsewhere. In Malawi, Davy (1925) regarded it as "the finest green manuring plant for Nyasaland." Green manure crops, such as *Mucuna* and *Crotalaria,* were planted on 600 000 acres annually in Zimbabwe in the 1950s (Rattray and Ellis, 1952). Traditionally, *Mucuna* has been used in Malawi as an intercrop with maize. A survey by Kabambe *et al.* (1998) of southern Malawian farmers found that 57% of them planted *Mucuna* at 5–7 weeks after maize to avoid deleterious effects on maize yield. Unfortunately, Gilbert (1997) found that late planting of *Mucuna* did not produce enough biomass to significantly enhance soil fertility. Of the farmers surveyed 100% used *Mucuna* for food, often boiling the bean for 8 h or more; 71% said that *Mucuna* improved soil fertility.

While *Mucuna* intercropping systems have been practised for generations in Malawi, the rotation of *Mucuna* with maize is relatively new. Kumwenda and Gilbert (1997) found *Mucuna* (5700 kg/ha biomass, 1770 kg/ha seed) rotations superior to *Crotalaria* (4300 kg/ha biomass, 800 kg/ha seed) and *Tephrosia* (2970 kg/ha biomass, 0) in terms of biomass production and seed yield when rotated with maize. Early incorporation of the green manures at flowering led to a significantly higher maize yield response than late incorporation after seed harvest. However, an economic analysis of the same data showed that late-incorporated *Mucuna* was the most profitable treatment if *Mucuna* seed was priced for sale.

In following experiments, Kumwenda *et al.* (1998) reports that average *Mucuna* biomass (6670 kg/ha) was greater than *Crotalaria juncea* (4870 kg/ha) or *Lablab purpureus* (4200 kg/ ha) at eight on-farm sites. Gilbert (1998b) found that *Mucuna* seed yield (2130 kg/ha seed) was greater than unfertilized maize (1680 kg/ha) grown at the same site. In addition, *Mucuna* has a copious amount of nitrogen-rich litter which falls during the season. *Mucuna* leaf litter fall was double that of soyabean in the same experiment. Even when the seed is removed, *Mucuna* rotations were found to add 100 kg N/ha into the soil for subsequent maize crops. This is higher than any other annual legume tested in Malawi (Gilbert, unpublished data).

The experiences of researchers with *Mucuna* in West Africa provide some insights into the opportunities and constraints of using *Mucuna* in southern Africa. Vissoh *et al.* (1998) report that the reduction of the weed *Imperata cylindrica* was the most important determinant of adoption of *Mucuna* in Benin. This illustrates an important point: *leguminous crops will not be adopted purely for a soil fertility benefit.* There must be corollary benefits perceived by farmers. In Malawi, there is some preliminary evidence that *Mucuna* rotations reduce the incidence of the parasitic weed *Striga asiatica*, which would be an important corollary benefit. Vissoh *et al.* (1998) also report that *Mucuna* rotations were most profitable when *Mucuna* seed was priced for sale, which is similar to our results in Malawi. With extremely high biomass production and seed yields, and a high soil fertility benefit for subsequent cereals, *Mucuna* managed as a grain legume rather than a green manure is a promising, sustainable cropping system for southern Africa.

However, if *Mucuna* is managed as a grain legume, then extreme care must be taken in processing the seeds for human consumption. *Mucuna* seeds contain L-Dopa, which can be toxic to humans if the seeds are not prepared properly. Lorenzetti *et al.* (1998) report a range of L-Dopa levels of 2.18–6.17% in 36 accessions of seed, and a maximum tolerable limit for L-Dopa of 1.5 g/person/day. Thus 100 g of unprocessed *Mucuna* seed would contain intolerable amounts of L-Dopa. In Malawi, the traditional cooking method for *Mucuna* involves repeatedly boiling the seed and discarding the water, for up to 8 h. Preliminary calculations indicate that the cost of fuelwood and water in this method is up to 10 times the economic value of the seed – clearly not a viable option for resource-poor smallholders. Fortunately, Versteeg *et al.* (1998) report a *Mucuna*-maize recipe based on traditional cooking methods in Benin that can reduce L-Dopa levels to 0.08–0.10% with total cooking time of 1 h. Improved *Mucuna* recipes that render seed both safe to eat and economic to prepare are a prerequisite to large-scale adoption of *Mucuna* in southern Africa.

COMPARISON OF BEST-BET LEGUMES

There are now several research and extension efforts underway to compare these best-bet leguminous systems in the same field and the same year to allow for direct comparison and farmer evaluation. Action Group I of the Maize Productivity Task Force has initiated a verification trial with all extension agents in Malawi (2000 sites) comparing fertilized maize, soyabean or groundnut rotations, maize/ pigeonpea intercrops and *Mucuna* rotations. In addition, a farmer-managed single replicate 'baby' trial design (three leguminous treatments plus a farmer control) has been introduced in conjunction with researcher-managed replicated 'mother' trials to increase farmer feedback, testing and adoption of legumes using participatory research methods (Snapp, 1998). MAFE has initiated 200 long-term minimum tillage trials which include maize/pigeonpea intercrops, soyabean rotations and *Tephrosia vogelii* undersown to maize. These comparisons are an effective way to present farmers with as many options as possible to allow them to choose cropping systems that best suit their needs.

RESULTS OF 'MOTHER TRIALS'

Table 1 shows the 2-year results of comparisons of best-bet soil fertility technologies for several 'mother trial' sites. The response of maize to fertilizer in year 1 was highly significant at all sites (Chitedze, Chitala and Bembeke). Maize yield response to *Mucuna* biomass application was significantly higher than the unfertilized maize at all sites. At Chitedze, note that the soyabean and *Mucuna* yields in 1997/ 98 were quite high, comparable to unfertilized maize yields. Pigeonpea yields were low at all sites tested, most probably due to insufficient rainfall during the seed filling period. There is a need to develop and test medium duration pigeonpea varieties for sites in Malawi without *chiperoni* rains.

Legume biomass of intercropped soyabean and pigeonpea and rotated *Mucuna* in 1997/98 was higher than other legumes, and this is reflected in the 1998/99 maize yield data. Maize yield following *Mucuna* was significantly higher than continuous maize and fertilized maize at Chitedze, as was maize following soyabean/pigeonpea. The 1998/99 maize yield trends were similar at Chitala, as the *Mucuna* and groundnut rotations were superior to continuous unfertilized maize. Maize/*Tephrosia* intercropped results were poor at the lower rainfall sites of Chitedze and Chitala. The most biomass was generated at Bembeke, which also had the highest maize yield increase under *Tephrosia* intercropping. The bean rotation and intercrop, as expected, had little effect on soil fertility due to the low biomass and poor nitrogen-fixing ability of common bean. Note that in terms of calories and protein produced the leguminous rotations and fertilizer treatments were generally superior to the intercrops. However, when an economic analysis was conducted using residuals, the legume rotations consistently ranked higher than both the fertilized and unfertilized maize.

Table 1. Best bet soil fertility technology 'mother trial' comparison results

Treatment	MZ yield 1997/98 (kg/ha)	Legume yield 1997/98 (kg/ha)	Legume biomass 1997/98 (kg/ha)	MZ yield 1998/99 (kg/ha)	Caloric output: 2 years (Mcal/ha)	Protein produced: 2 years (kg/ha)	Economic residual: 2 years (rank)
BEMBEKE							
MZ	920	–	–	1080	7240	200	4
MZ + F	1590	–	–	2510	14890	410	7
MZ/BN	710	290	–	1170	8510	310	5
MZ/BN + F	1280	410	–	1990	14730	530	6
MZ/TV	720	0	6980	1900	9500	260	2
BN–MZ ROTATION	–	300	–	1380	6030	210	3
MP–MZ ROTATION	–	790	2700	2390	11340	430	1
F test	***	***	–	***	***	***	
LSD 0.05	440	90	–	510	1790	50	
CHITALA							
MZ	950	–	–	2240	11580	320	4
MZ + F	1710	–	–	4170	21340	590	6
MZ/PP	630	0	3980	2970	13040	360	3
MZ/PP + F	1340	0	2930	3920	19090	530	7
MZ/TV	780	0	1260	2060	10330	290	5
GN–MZ ROTATION	–	1520	2950	3330	20910	1130	1
MP–MZ ROTATION	–	1160	6230	4700	21030	750	2
F test	***	***	***	***	***	***	
LSD 0.05	350	370	1890	940	3660	140	
CHITEDZE							
MZ	1680	–	–	1610	11930	330	3
MZ + F	3480	–	–	2270	20850	570	6
MZ/PP	1040	0	4320	1610	9600	260	5
MZ/PP + F	2810	0	2660	2870	20650	570	7
MZ/TV	1610	0	2920	1530	11400	310	4
SB/PP–MZ ROTATION	–	1720 (SB)	6570 4130 (SB) 2440 (PP)	2930	17230	900	1
MP–MZ ROTATION	–	2130	7940	3250	19030	840	2
F test	***	***	***	***	***	***	
LSD 0.05	1030	360	1530	740	4750	150	

*,**,***, *F* test significant at $P < 0.05$, 0.01, 0.001, respectively.
MZ, sole maize (MH 17 or MH 18).
MZ + F, sole maize fertilized at rate of 69:21:0 + 4S.
MZ/BN, maize intercropped with common bean.
MZ/BN + F, maize intercropped with common bean and fertilized at rate of 69:21:0 + 4S.
MZ/TV, maize undersown at first weeding with *Tephrosia vogelii* at 20 kg/ha.
BN–MZ rotation, crop rotation of common bean followed by sole maize.
MP–MZ rotation, crop rotation of *Mucuna pruriens* (velvet bean) followed by sole maize.
MZ/PP, maize intercropped with ICP 9145 pigeonpea.
MZ/PP + F, maize intercropped with ICP 9145 pigeonpea and fertilized at rate of 69:21:0 + 4S.
GN–MZ rotation, crop rotation of CG7 groundnut followed by sole maize.
SB/PP-MZ rotation, crop rotation of Magoye soyabean intercropped with ICP 9145 pigeonpea followed by sole maize.

The preliminary results of this trial are extremely encouraging. The grain legume and *Mucuna* rotations provided high seed yields, good soil fertility benefits, and high economic returns. This trial is continuing for a third season in 1999/2000, and analysis of nitrogen added and economic net benefits will be conducted for all three seasons.

FUTURE RESEARCH NEEDS

While there have been several promising best-bet leguminous systems identified for Malawi, there are still several hurdles to overcome to ensure a diversified and sustainable cropping system with an increased legume component.

Some of these obstacles are discussed below.

Multiple uses for legumes

As mentioned above, legumes in land-constrained areas are unlikely to be adopted solely for soil fertility benefits. The greater the number of perceived benefits of a leguminous crop, the more likely it is to be adopted. Clearly there is a need for further study on the human consumption of species such as *Mucuna pruriens* and *Canavalia ensiformis*. These species have demonstrated superior growth and yield in Malawi, partly due to toxins which give them partial resistance to insect attack, but also render the seed difficult to prepare safely. *Tephrosia vogelii* also contains the toxins, tephrosin and rotenone, which has led to interest in its use as insecticide. Quantifying the effect of these legumes on the incidence of the noxious weed *Striga asiatica* is also important, as this is one of the major biotic constraints to maize production in southern Africa.

Pest and disease complexes on legumes

Leguminous technology is not without risk for the smallholder farmer. Just as a cash investment in inorganic fertilizer can be lost due to drought, an investment in land, labour and seed to legumes can be wiped out to pests and diseases. There are some diseases, such as *Fusarium* wilt on pigeonpea, *Curvularia* leafspot on *Mucuna* and rosette on groundnut, which have manifested themselves in Malawi in recent years and can drastically reduce plant biomass, yield and soil fertility benefit. There is a need for as diverse a selection of leguminous germplasm available as possible to research resistance to these diseases and present a wide array of leguminous options to small-scale farmers.

Legume screening and germplasm exchange

As mentioned above, changing pest and disease pressures can render dependence on just a few leguminous accessions extremely risky. In addition, changing economic scenarios can render promoted legumes less attractive to farmers. Active legume screening efforts are valuable to identify and feed future best-bet legumes into the extension network. Several green manure species, such as *Canavalia ensiformis, Crotalaria grahamiana* and *Crotalaria ochroleuca,* have been identified as good performers in the agro-ecology of the Lilongwe plain (Gilbert, 1998a). Similar efforts in Kenya have identified suitable legumes for diverse agro-ecologies throughout Kenya. There is a need for a technical clearinghouse of information and germplasm exchange for promising legume species.

Economic and policy issues

There are several leguminous technologies which have performed well based on biophysical and socio-economic criteria in Malawi. However, some key constraints to their adoption remain. Not enough information on labour use is known for some of the technologies (e.g. *Mucuna*). Seed availability and market for seed are also crucial factors. The unavailability of improved legume varieties at the village level, and the long lead time for seed multiplication of legumes such as groundnut, frustrate increased demand for seed. In addition, farmers are uncertain of the output prices they will receive for legumes, which reduces the land they are willing to commit to legume production. Furthermore, adding value to legumes such as pigeonpea and soyabean through processing needs to be addressed by policy-makers.

Integrated nutrient management

For a country such as Malawi, where farmers do not have enough land to devote to leguminous fallows, nor enough cash to buy high rates of inorganic fertilizer, there is a chance that the combination of lesser amounts of both is the way forward. Palm *et al.* (1997) discuss the state of knowledge on the combination of organic and inorganic sources of fertility and conclude that a systematic framework for guidelines on integrated nutrient management is needed. It is also unsure if there is an interaction between the two nutrient sources. The yield responses seen are often due to simple additive effects of nutrients.

However, even an additive effect might be helpful if the combination more efficiently uses scarce farm resources. Another topic which requires further research is the issue of the fate of nutrients added in leguminous biomass. Ideally, farmers should know the fertilizer equivalency for subsequent cereals of planting different legumes on different soils in different climates. This is difficult to do, since leguminous biomass nutrient decomposition pathways are notoriously leaky. Nitrogen added in biomass, for example, can be lost due to leaching, volatilization of ammonia, denitrification, termite offtake, etc. Finding practical management practices which minimize nitrogen losses would make adoption of leguminous technologies more attractive to resource-poor smallholders.

CONCLUSION

Malawi's biophysical and socio-economic environment has led to a greater farmer interest in legumes in recent years. Several best-bet leguminous cropping systems have been identified which are superior to continuous unfertilized maize in terms of returns to cash, calories/ha, and soil fertility improvement. However, challenges remain for research and extension personnel to address, such as improved human utilization, reduced pests and diseases, and identifying promising leguminous accessions. If these challenges are met, legumes will play an important role in diversifying the Malawian farming system and ensuring improved household food security.

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DISCUSSION

D. Coyne. Is there any information on the implication of *Tephrosia* intercropping on the nematode situation?

R. A. G. Not really.

Dr A. T. Daudi. *Tephrosia* is susceptible to *Meloidogyne* root-knot nematodes and we have scored high infestations in the FSIPM trials. There is a need for more work in liaison with nematology staff on an integrated approach to crop production because if tobacco farmers use *Tephrosia*, more nematode damage will be encountered in tobacco fields.

R. Jones. What farmer reaction are you getting to the different treatments?

R. A. G. Dr Snapp's team has conducted participatory research on leguminous systems which indicates that farmers preferred maize-pigeonpea systems to maize–*Tephrosia* systems. At our trials, farmers are sceptical of *Mucuna* in the first year, but ask for seed in year 2 after they see the maize yield benefits.

C. R. Riches. Is there any evidence that there may be a yield decline in biomass, or even that there may be establishment problems with *Tephrosia* when it is planted year on year?

R. A. G. We are only in the second or third season at our trial sites, so we have not seen obvious yield decline yet at our sites.

Soil fertility options for Malawi smallholders: integrated legume systems

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ABSTRACT

Promising legume intensification systems were evaluated in partnership with farmers at five case study sites in Malawi. The biological performance under farmer management, in stressed environments, suggested that the legume 'best-bet' systems can perform as well or better than sole crop maize, across a wide range of agro-ecosystems. Over 2 years, yields of legume-maize best-bet systems were consistently about 25% higher than yields of sole cropped maize. The highest performer was the groundnut/pigeonpea intercrop and maize rotation system, which produced 60 kg N/ha in legume residues the first year and a 900 kg increase in maize yields the second year. Sixty-seven farmers who conducted on-farm trials evaluated the best bets by matrix ranking. The two pigeonpea-intercrop systems were ranked highest. Ranking was markedly consistent across the five different agro-ecosystems. An in-depth survey of crop and soil management practices was conducted at two of the case study sites with 239 farmers. The results from the survey indicated that current practices prioritize maize production, and the primary management strategy for residues is to burn them. The farmer participatory trials indicated strong farmer interest in trying new, legume-intensified systems. However, the survey data indicated barriers to deriving soil benefits from new systems, including minimal farmer knowledge concerning legumes, and limited interest in residue incorporation.

INTRODUCTION

Maize dominates in subsistence agriculture of southern Africa, and nowhere more so than in Malawi (Kumwenda *et al*., 1997). The sub-humid tropical agro-ecosystems of Malawi are characterized by a long dry season, with unimodal rains that generally occur between November and April. Annual precipitation varies from 600 mm to 1400 mm; 90% of the country has a mean annual rainfall of more than 800 mm (Materechera and Mloza-Banda, 1994).

Malawi is located at the bottom of the Great Rift Valley and is characterized by a wide range of relief, with altitudes from 100 m to >2000 m above sea level. Average temperatures are above 15 °C for 95% of the farm sector and agricultural potential is generally high.

Malawi soils are generally alfisols or ultisols of moderate fertility and deep profiles (Snapp, 1998). Very low fertility soils are also present, including weathered oxisols and shallow, eroded soils on steep, deforested sites. Soil fertility has declined with continuous maize production, minimal use of fertilizers and a growing population which has precluded use of traditional fallow systems (Kumwenda *et al*., 1997). Land is continuously cropped because of the high population density (>80/km^2), and farm size for smallholders is about 1–3 ha.

The Malawi smallholder sector consists primarily of maize, hand cultivated with a ridge/furrow system. It is grown both as a sole crop and as an intercrop with a wide range of minor crops at a low density. Intercropped maize accounts for over half of the land area in the densely populated southern region, where maize/pigeonpea (*Zea mays/Cajanus cajan*) and maize/groundnut (*Arachis hypogaea*) are the most widely grown cropping systems (Kanyama-Phiri *et al*., 1998; Shakson and Tauer, 1992). Cassava is also an important secondary crop in some areas. Tobacco is generally the primary cash crop, although cotton is also grown in drier areas. In high- to mid-altitude regions, common bean (*Phaseolus vulgaris*) is widely grown, primarily as an intercrop with maize. Soyabean (*Glycine max*) was recently introduced and in 1998 accounted for 5% of grain production (FEWS 1999). Other grain legume crops are grown on a minor scale, including cowpea, mucuna and ground bean. In central and northern Malawi, groundnut is the most common legume and it is grown as a sole crop, often as a cash crop as well as for home consumption.

The overwhelming dependence on maize indicates a system vulnerable to economic or biological disturbance. Diversification with legumes has been promoted by various church groups and NGOs, as a means to enhance human nutrition through protein-rich crops, and to improve soil fertility through biological nitrogen-fixation. Yet grain legumes are a small part of the cropping system: legume grain has remained at about 15% of total production in the 1990s (FEWS). The high labour demands required to grow legumes, and relatively low market prices, may have contributed to this situation.

Adoption of grain legumes is low, but green manure legume crops is even lower – green manures are almost never

Table 1. Biophysical characteristics of five agro-ecozones where farmer participatory research was conducted

Agro-ecozone	Altitude range (m a.s.l.)	Annual rainfall range (mm)	Rainfall pattern	Soil texture, primary soil types, farmers' fields	Soil organic C (mg/kg)	Soil pH
North central Malawi mid-altitude plain	1000–1300	600–800	Dec–Apr	Sand, loamy sand	15	6.4
Central Malawi mid-altitude plain	1000–1200	800–1000	Nov–Apr	Sandy loam, loamy sand	16	5.8
Central Malawi high-altitude hills	1400–1700	800–1000	Nov–Apr	Sandy loam, loamy sand, sandy clay loam	12	5.5
Malawi central and south lakeshore	200–500	600–800	Oct–Mar	Sand, loamy sand	14	6.9
Southern Malawi mid-altitude	1200–1500	1000–1200	Oct–May Sporadic: Jun–Aug	Sandy loam, loamy sand, sandy clay loam	11	6.6

Climate data from 10-year averages collected at extension EPA headquarters (1988–98), and soil characteristics are presented from on-farm field trial data collected in 1998.

used in Malawi. Since the 1930s there have been numerous efforts to promote the use of green manure species such as mucuna, sunnhemp and lablab, to enhance soil fertility through rotational and intercrop systems (Snapp *et al.*, 1998). Yet farmers grow few legumes of any type, with low productivity. Not only is growth limited, but residues are often burned by farmers to reduce weed seed banks and ease labour required for land preparation. Gaseous losses of nitrogen from burning residues greatly reduces residue contributions to soil fertility. Residue production and management is of critical importance for secondary, soil enhancing or livestock feeding benefits from legume systems. Although research station grain yields are consistently over 2.5 t/ha^2, farmer grain legume yields remain around 0.6 t/ha^2 (FEWS). Residue yields follow a similar pattern. Legumes are often grown as low density intercrops with less than one legume plant per maize plant in the field (Kanyama-Phiri *et al.*, 1998). Low density planting, low growth rates and minimal management all contribute to low yields of grain and residues.

Currently in Malawi, the most widely grown legume is groundnut, both as an intercrop with maize and as a sole crop. Other important legumes are pigeonpea, common bean and, more recently, soyabean. All of these species, with the exception of common bean, have the potential to produce significant amounts of high quality residues under on-farm conditions. However, in this paper we contend that soil resources do not automatically benefit from legume-intensified systems. Necessary conditions include the right choice of species and variety, prioritization of legumes that produce sufficient amounts of high quality residues, agronomic practices that promote productivity, and residue management practices that maximize nutrient recycling. We hypothesize that long duration legumes (short lived perennial legume species managed as annuals, e.g. *Tephrosia vogelii* and pigeonpea) and legume/legume intercrops may be 'best bets' for legume-intensified systems that fit farmer criteria, and improve the soil.

This paper reports on a 2-year study to evaluate, in a smallholder farm environment, potential legume-intensification systems for Malawi. We tested on-farm performance of three best-bet, legume-intensified systems at case study sites selected to represent five major agro-ecozones in Malawi. Biological productivity of the legume-intensification systems was quantified, including yields, calories and nitrogen contribution of legume residues produced. System performance was also evaluated by farmers through a matrix ranking exercise. A complementary, formal survey of farmer practice was carried out in two of the case study areas. The survey characterized soil and crop management, and evaluated constraints and opportunities for adoption of best-bet options. Our goal was to document potential benefits and consequences of integrating more legumes into a maize-dominated cropping system.

MATERIALS AND METHODS

On-farm experiments

Site selection and characterization

Trials were conducted in five agro-ecozones and two villages were chosen as representative of each agro-ecozone. The five agro-ecozones were: north central Malawi semi-arid mid-altitude plain, central Malawi sub-humid mid-altitude plain, central Malawi sub-humid high-altitude Dedza hills, southern Malawi high rainfall, sub-humid mid-altitude zone, and the low rainfall, semi-arid low altitude lakeshore zone (Table 1). The research sites are shown in Figure 1. The two villages selected were about 25 km apart for the northern mid-altitude site 1, and 50 km apart for the central mid-altitude plain, sites 2A and 2B. The villages were 180 km apart for the dry lakeshore plain, sites 3A and 3B, and about 25 km apart for sites 4 (central high-altitude) and 5 (southern mid-altitude).

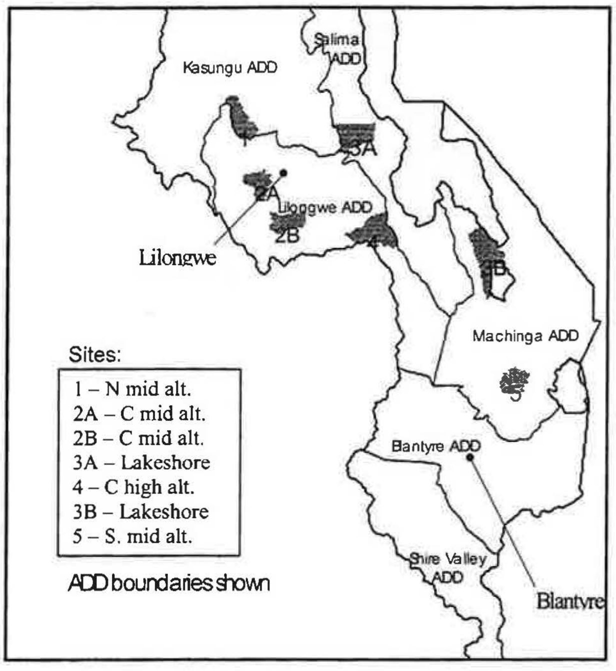

Figure 1. Map of central and southern Malawi with case study sites representing five agro-ecosystems indicated by the associated extension planning area (EPA). The EPA is an extension administrative sub-unit of the eight agricultural development divisions (ADD) in the country.

Trial design

At each village researchers met with farmers and presented the proposed research plan to evaluate best-bet, legume-intensified systems. Farmers were asked to volunteer to host trials at group meetings, where researchers asked the community to help select a wide range of farmers from among the volunteers. Attention was given to including farmers from diverse backgrounds: relatively well-off and resource-poor families, younger and older families, and male and female-headed households. Farmer evaluation of legume-intensification technologies was facilitated by the use of a simple trial design easily understood by farmers (Snapp, 1999). There were four plots of 8 x 8 m at each farmer field site. Four plots allowed evaluation of three treatments plus a farmer control plot of continuous sole crop maize. Trials were usually laid out as a large block, so farmers could stand in the middle of the trial and easily compare the four plots (each plot was one corner of the square).

Each farm site was a replicate, with 10 villages x an average of 10 farmers/village hosting the legume best-bet trials, for a total of 100 farmers. The simple trial design and use of farmers as replicates has been promoted recently as a methodology which allows sampling of a wide range of farmer management practices and different field environments (Mutsaers *et al.*, 1997). Usable data was obtained from 67 trials, as livestock damage, flooding or poor stands limited data obtained from some trials. On-site enumerators were based at all sites to assist extension staff and farmers to manage and monitor the trials. Measurements included: soil sampling and analysis, planting date, weeding dates and, for each crop, population density at emergence and at harvest, grain yields, and legume residue biomass. Residue measurements were conducted at a subset of about 30% of the trials. In October 1997, before trials were initiated, soil samples from 0–20 cm depth were collected, from a composite of 10 sub-samples. Soils were analysed for pH (1:2 water), texture, and soil nitrate-N in 2 M potassium chloride extract.

A pairwise matrix ranking exercise was conducted to allow all of the farmers who carried out trials to evaluate the technologies. In addition to farmer evaluation, technologies were compared on the basis of yields, calories produced and total amount of nitrogen in residues. Adaptability analysis was conducted to compare technology performance for the widely varying environments on the basis of an environmental index, the average calories produced at each site (Mutsaers *et al.*, 1997).

Legume best-bet technologies

Researchers met at the start of the project and developed hypotheses regarding which legume-intensification technologies would meet farmer criteria. Researchers decided that to be a 'best- bet', legume-intensified system, the technology must produce as many calories as unfertilized maize, each year. This was to reduce the risk associated with farmers trying out soil-fertility improving technologies. The other criteria for developing best bets was the ability, in a researcher's judgement, to produce consistently at least 2 t/ha of residue biomass, and 50 kg/ha total N quality.

The best-bets legume systems were chosen on the basis of past findings from the literature and unpublished research from on-farm trials conducted by the Malawi Ministry of Agriculture Department of Research and Technical Services, the University of Malawi Crop Science Department and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). A consensus of seven researchers' experience was developed. These best bets were hypothesized to be good performers in on-farm environments, but they were also designed to take farmer constraints into account (Table 2). For example, a 100 000/ha groundnut population density is recommended by researchers to obtain a good groundnut stand and thus, high yields and biomass, but groundnut seed is expensive. Small-scale farmers are generally interested in maximizing groundnut yield return from seeds planted, thus, 66 000 plants/ha was used as the best bet for groundnut population in these trials.

The technologies were also designed to minimize labour requirements. *Tephrosia vogelii* was chosen as the best-bet green manure species due to its widespread adaptation and ability to produce consistently at least 2 t of residue biomass on-farm (R. Gilbert, unpublished data, 1997). The pigeonpea variety used, ICP 9145, is a long season type with *Fusarium* wilt resistance. Erect groundnut varieties were used because of improved yield potential and ease of harvesting compared to spreading varieties. Farmers chose whether to grow a shorter season groundnut variety, JL 24, or a longer season variety, CG 7. A soyabean variety, Magoye, was used instead of groundnut in the cool central Malawi high-altitude region.

Table 2. Soil fertility-improving technologies described in terms of biological and farmer considerations

Technology	Population density (×1000)	Biological characteristics	Farmers' perceptions of characteristics
	Maize: 37	Maize hybrid MH18, 3 maize plants/ planting stations, 0.9 x 0.9 m.	Current farmer practice throughout Malawi.
1. Maize control	Maize: 37 pigeonpea: 37	Temporal compatibility. Pigeonpea variety ICP 9145 planted at the same time as maize, 3 plants/planting station spaced halfway between each maize station. Pigeonpea grows slowly, which reduces competition with maize.	Pigeonpea is a bonus crop, low density system minimizes impact on maize yields.
2. Maize + pigeonpea intercrop	Groundnut: 74 pigeonpea: 37	Groundnut variety JL 24 or CG 7 was grown as a single row on ridges spaced at 0.9 m spacing. To enhance residue biomass quantity and quality, a 'bonus' pigeonpea crop is intercropped with the short duration grain legume.	Legume seed density takes into account expense of groundnut seed and farmer-adoptable seeding rates. Pigeonpea is a bonus crop.
3A. Groundnut + pigeonpea intercrop year 1, rotation with maize year 2	Soyabean: 222 pigeonpea: 37	Same as groundnut + pigeonpea, except a double row of 10 cm spaced soyabean planted along each ridge. Indeterminate variety Magoye that does not require inoculum (nodulates with indigenous *Rhizobium*) used, to maximize performance under on-farm conditions.	Higher density of seed is possible given that seeds are smaller and cost is cheaper than groundnuts. Pigeonpea is a bonus crop.
3B. Soyabean + pigeonpea, rotation with maize year 2	*Tephrosia*: 20 kg/ha maize: 37	Temporal compatibility, enhanced by planting *Tephrosia* at first weeding. *Tephrosia* has an initially slow growth habit. Green manure screening studies have shown the widespread adaptability of *Tephrosia* to Malawi agro-ecosystems, producing about 2 t/ha as a relay intercrop.	For a green manure system to be adopted by farmers, it must minimize the labour required. Seed is broadcast along ridges and incorporated during weeding.
4. Maize + *Tephrosia* relay intercrop			

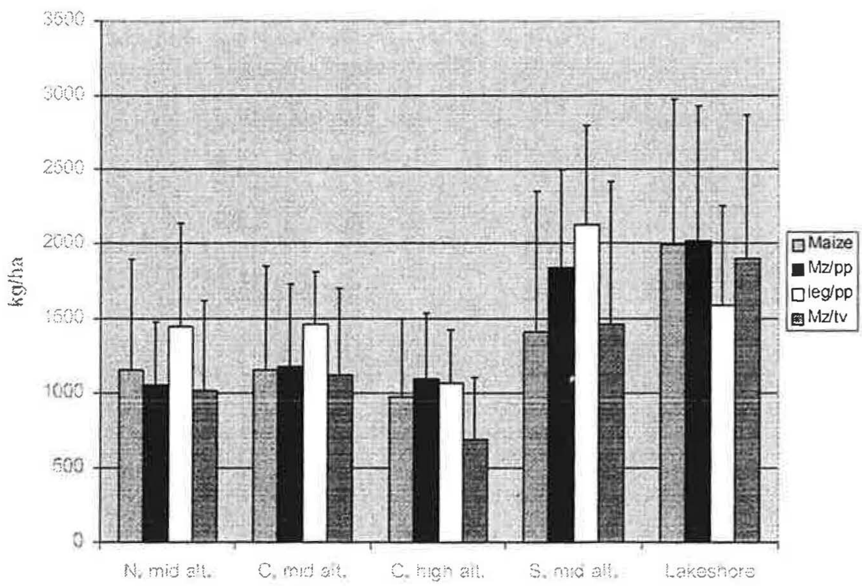

Figure 2. Maize plus legume grain yields presented as the average, total yield produced for each best-bet technology in 1997/98 growing season (standard deviations from the average are presented as a bar). These data are from the first year, the grain legume intercrop phase for the rotation technology. Data presented from 67 trials conducted in five Malawi agro-ecozones.

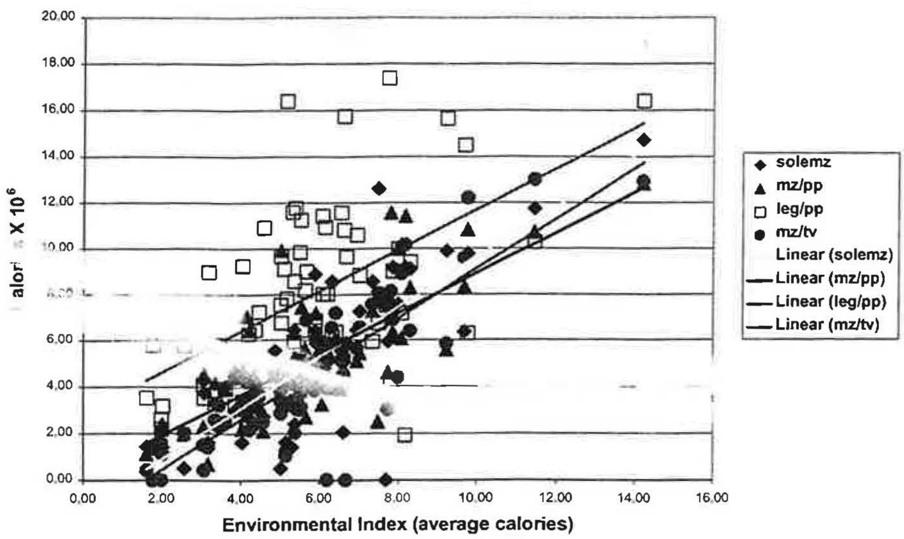

Figure 3. Calories produced per technology presented in relation to average calories per trial site, data from 67 trials conducted in 1997/98. Trend lines are the linear regression for each technology.

Survey of crop and soil management

Based on findings from informal surveys of farmer practice in the five agro-ecozones, a formal survey was implemented at two of the study sites. The two drier, more drought-prone, semi-arid agro-ecosystems were chosen for the survey, the Chisepo area to represent the northern Malawi mid-altitude plain, and the Mango[illegible] represent the lakeshore [illegible] was [illegible]plemented in March 1999 using a questionnaire designed by Dr D. Rohrbach of ICRISAT-Zimbabwe and modified by Dr S. Snapp, to meet Malawian conditions. In all 239 farmers were interviewed after being chosen randomly from village lists of households (a back-up random list was chosen to substitute any farmers missing during the interview process). Mr F. Simtowe supervised the survey data management using SPSS software and conducted extensive quality control checks before developing the descriptive statistics presented here.

RESULTS AND DISCUSSION

Legume-intensified technology: biological performance

Yields of the legume-intensified best bets are presented in Figure 2 for the 1997/98 growing season from 67 on-farm trials. Note that the yields presented are combined, including maize grain yield plus pigeonpea yields for the maize/pigeonpea intercrop system, and pigeonpea yields plus groundnut (or soyabean) yields for the legume intercrop technology. Total grain yields varied from 700 kg/ha to 2200 kg/ha, with higher yields consistently obtained in the Southern Malawi and Lakeshore agro-ecosystems. Annual rainfall in 1997/98 was about 1200 mm at these sites, compared to 1000 mm rainfall at the other sites. This might in part explain the higher yields.

A particularly interesting finding was the consistent yields across technologies for each agro-ecosystem. This suggests that the legume-intensive technologies met the researcher-defined criteria, which was that each best-bet technology should produce as much as the control (unfertilized sole maize crop) across a wide range of environments. When technology performance was evaluated in terms of calories produced, then the legume/legume intercrop technology was outstanding (Figure 3). This 'doubled-up legume' best bet produced similar grain yields, but more calories. The [illegible] number of calories produced was due to the oil-ri[illegible] of groundnut and soyabean grain, which translates to about 45% higher calories per equivalent amount of maize or pigeonpea grain. The higher calorie yield is often related to higher economic yields as well, though we did not attempt to calculate economic returns for the different technologies in this paper.

Pigeonpea yields were very low to no yield at all at the central and northern Malawi sites due to livestock damage. In fact, pigeonpea in these best-bet technologies acts as a bonus grain crop: pigeonpea yields were obtained in some agro-ecozones, in other areas, no yields were harvested. However, residue yields were consistently high with pigeonpea across the different agro-ecozones. At least 28 kg N/ha was accumulated in pigeonpea residue at all sites (Figure 4). Earlier work in Malawi has indicated the potential of pigeonpea to contribute significant amounts of high nitrogen residues. MacColl (1989) showed that the grain yield of maize following a pigeonpea crop averaged 2.8 t/ha, one-third higher than yields of continuous maize that had received 35 kg N/ha each year. Similar findings in terms of pigeonpea contributions to cropping system nitrogen status were presented by Kumar Rao *et al.* (1983). However, previous research reports have generally evaluated pigeonpea performance under high fertility soils and under researcher management. This includes pesticide application which smallholder farmers in Malawi cannot afford.

As far as we are aware, the data presented in Figure 4 is the first published example of nitrogen accumulated in legume residues of maize/pigeonpea and grain legume/pigeonpea intercrops grown in a Malawi smallholder field environment, under low fertility soils and farmer management. The total amount of nitrogen in the residues of the legume/legume intercrop was about 60 kg N/ha, meeting the target set for

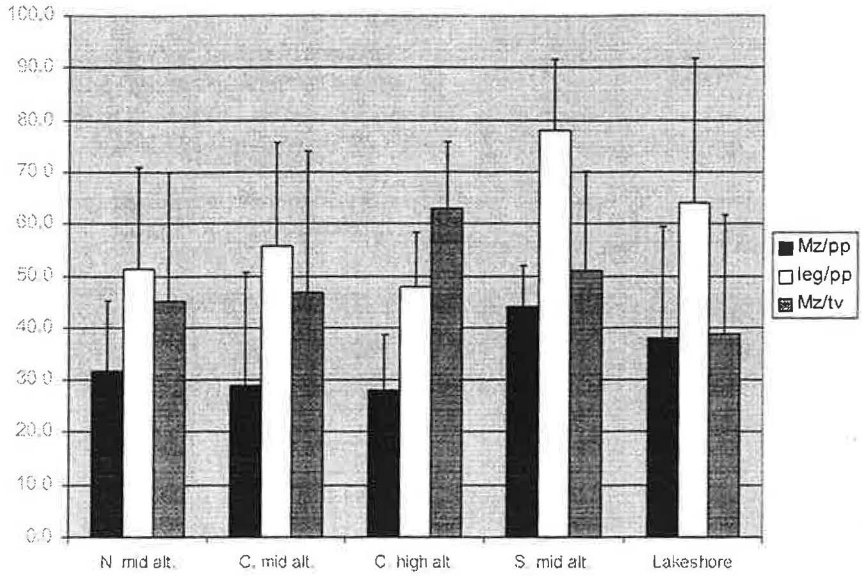

Figure 4. Total nitrogen accumulated per hectare in legume residues for each technology in the 1997/98 growing season; average data from 30 trials. These data are from the first year, where the rotation technology was in the grain legume intercrop phase. The data are presented by agro-ecozone.

the best bets. The maize/*Tephrosia* intercrop also performed well, but the nitrogen accumulated was more variable. Literature reviews of the nitrogen contributed from biological nitrogen-fixation in legume-intensified cropping system has indicated that extremely variable rates are possible (Danso, 1992). For example, estimates of nitrogen from BNF in groundnut residues varies from 20 kg N/ha to 220 kg N/ha. The grain legume systems, in our study, were more consistent at producing high nitrogen content residues than the green manure system with *Tephrosia*. This may have been due in part to poor stand establishment of *Tephrosia* at some sites, particularly in sandy soils.

The important question is, does the residue nitrogen incorporated from the best bets translate into yield improvements in the second year? The data presented in Figure 5 are from the second year and are very encouraging. The legume-based best bets increased yields by about 30% overall compared to the unfertilized sole crop maize (average about 1400 kg/ha). In the highest performing technology, maize yields were increased to about 2300 kg/ha. This was for maize grown in rotation with a doubled-up legume intercrop of groundnut and pigeonpea (or a soyabean/pigeonpea intercrop in the central Malawi highland agro-ecozone). This is in the range of the 2 t/ha that Giller and Cadisch (1995) speculate can be supported by legume-based improvements of tropical agricultural cropping systems. These results support the findings of Hulugalle and Lal (1986), where pigeonpea grown as a sole crop in rotation with maize, increased maize yields by about 50% compared to maize grown after maize in sub-humid Nigeria. We did not see changes in soil organic carbon in our study (data not presented), nor did we expect to see a detectable change in the first 2 years. However, it is promising that Hulugalle and Lal found enhanced soil organic carbon from a pigeonpea/maize rotation after four growing seasons, compared to soil organic carbon in a continuous maize system.

The legume residues in our study varied from 1.5% to 3.5% N. The levels were lower and more mixed compared to other studies of agroforestry technologies (Ikerra *et al.*, 1999; Mafongoya and Nair, 1997). This may reflect the wide range

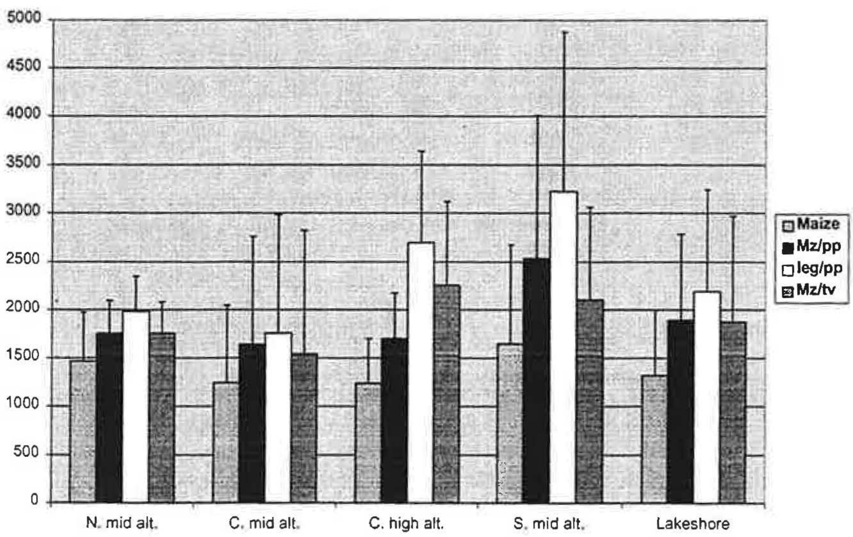

Figure 5. Maize plus legume grain yields presented as the average, total yield produced for each best-bet technology in 1998/99 (standard deviations from the average are presented as a bar). These data are from the second year, the maize phase for the rotation technologies. Data presented from 60 trials conducted in five Malawi agro-ecozones.

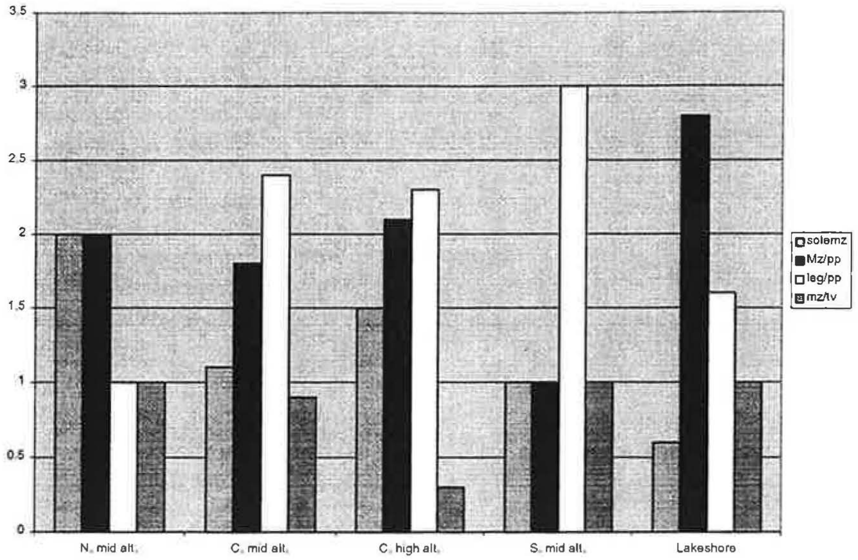

Figure 6. Farmer ranking of the four technologies tested in on-farm trials, using a pairwise ranking matrix. All farmers who participated in trials evaluated them through this matrix ranking survey.

of fertility status in farmers fields sampled in this on-farm study. Further, the 'best-bet' systems we studied prioritized practical options which farmers might adopt, including late residue incorporation and removal of legume grains in some cases. Thus nitrogen content in the residues was expected to be variable and low, due to leaf maturity and nitrogen removal as grain. Variable quality residues with moderate nitrogen content is expected to release nitrogen at a moderate rate, with an estimated 10–25% of the total nitrogen available to subsequent crops (Giller and Cadisch, 1995).

In our study the average nitrogen content of pigeonpea/ groundnut residues was 60 kg N/ha, equivalent to 20 kg N if the assumption is made that 33% of the nitrogen might be released after incorporation. Thus residue nitrogen supplied about 20 kg N/ha, which supported an average increase of 900 kg of maize grain. This does not take into account any root nitrogen, and rotation effects, which may have contributed to the yield increase. From these assumptions, an estimate of nitrogen use efficiency can be made, 45 kg grain/kg available nitrogen from legume residues; this is a very high degree of efficiency. The potential for high efficiency from pigeonpea residue nitrogen is supported by the findings of Mafongoya and Nair (1997) at a sandy site in semi-arid Zimbabwe. They found that pigeonpea residues were among the most consistent suppliers of nitrogen to subsequent maize crops, when compared to a wide range of agroforestry species.

The moderate nitrogen levels in residues, and mixed quality of leaves in our legume best-bet systems, may have increased the synchrony of nitrogen release compared to maize nitrogen demand. As hypothesized by Myers and colleagues (1994), synchrony of residue nitrogen release can greatly influence nitrogen use efficiency of organic nitrogen sources. Phiri *et al.* (1999) also found highly variable nitrogen quality and synchronized, moderate release pattern for nitrogen produced on-farm in *Sesbania sesban* residues. Phiri's work evaluated a relay intercrop agroforestry system with maize, in a watershed that included the southern Malawi case study site reported on here. They suggested that on-farm nitrogen release may be more synchronized with maize growth than earlier work had indicated. However, research at a nearby research station site in southern Malawi demonstrated that fast release of nitrogen is possible in agroforestry systems, as indicated by early season soil inorganic nitrogen levels associated with incorporating high nitrogen *Gliricidia sepium* residues (Ikerra *et al.*, 1999). Further research may be required to evaluate nitrogen release and synchrony with maize uptake from the mix of medium and high quality residues associated with the legume-intensified systems studied here.

Legume-intensified technology: farmer evaluation

Farmer ranking of the legume-intensified technologies was consistently high (Figure 6). In a pairwise comparison, the two pigeonpea intercrop systems were ranked the highest overall, with a ranking of 2 or more at almost all sites. The ranking of the *Tephrosia vogelii* intercrop technology was moderately high, and may improve in the future as the soil fertility benefits are demonstrated. This technology is an intercrop green manure system with more of a focus on longer-term benefits compared to the other two best bets which include grain legumes. There was no marked effect on ranking of technologies by farmer characteristics, such as gender, household wealth or site where the farmer was located. A more in-depth analysis has still to be conducted to determine if farm typology influences criteria for evaluating technologies.

The current predominant system in Malawi, sole crop maize grown with little or no fertilizer, was ranked around 1. This was the lowest ranking overall. This was a surprising result because this technology is in some ways the farmers current best bet, as indicated by widespread production of sole cropped maize documented in the survey (Table 3). The relatively high rankings for the best-bet systems may reflect in part farmer attempts to please the researcher conducting the survey. However, similar results were obtained from a

Table 3. Primary crops grown presented as average percentage of land cultivated to each crop in 1997/98 growing season for two case study areas

Crop	Chisepo		Mangochi	
	Male-headed households (%)	Female-headed households (%)	Male-headed households (%)	Female-headed households (%)
Maize	50.6	60.2	73.4	74.5
Tobacco/cotton	28.3	12.3	11.5	5.0
Groundnut	12.9	21.6	5.8	4.0
Other legumes	5.9	4.2	1.9	0.9
Cassava	1.5	0.5	4.0	4.4
Miscellaneous	0.6	0.8	3.0	8.1

Data from survey of 239 households in Chisepo (north central Malawi, mid-altitude) and Mangochi (southern lakeshore). Farmers were randomly chosen from village lists of all families in the area.

separate rating exercise that was carried out with the 100 farmers that participated in conducting trials in 1997/98 (Table 4). It was interesting that both the ranking and the rating exercises indicated that the two pigeonpea intercrop systems were the most preferred technologies. The best test of farmer ranking of technologies and overall interest will be conducted in the future through an evaluation of farmer adoption of the technologies.

Farmer constraints and opportunities for adoption

Two case study areas were chosen to conduct an in-depth, detailed survey of farmer practice. Both the villages where the trials were conducted and nearby villages where no intervention was attempted were included in this baseline survey. As we have only been working in these sites for 2 years it was not expected that there would be any difference in the intervention and control, non-intervention villages, in terms of farmer knowledge of legumes or farm practice. No difference was found and the data presented are averaged across four villages per site, for both Chisepo (northern mid-altitude plain) and Mangochi (lakeshore). The socio-economic characteristics of the farmers were similar to those reported elsewhere for smallholder communities in Malawi, with an average farm holding size of 1.8 ha and 2–4 adults/household with about four dependent children.

Our data indicated that labour constraints experienced by farmers may be severe despite the relatively high population levels in Malawi. This is in part due to the timing of labour shortages, which primarily occurred early in the growing season when land preparation, tobacco establishment, weeding and fertilizing all require labour. Our survey data also indicated that female-headed households face high labour constraints and do not hire labour, in contrast to male-headed households. The survey findings supported research findings from Malawi that gender should be considered regarding labour constraints and decision-making for legume production (Ferguson, 1994). Further, an evaluation of adopters of improved groundnut production systems found that labour constraints are one of the biggest concerns of women farmers, particularly female-headed households (Kolli and Bantilan, 1997).

Table 4. Farmers' rating of technology traits across all sites

Technology	Weeding and labour requirement	Seed availability	Contribution to food security	Contribution to cash sales	Contribution to soil fertility
Maize	3.1	3.3	2.2	2.3	1.5
Maize + pigeonpea	2.5	1.9	3.4	2.9	3.1
Groundnut + pigeonpea*	2.2	1.7	3.3	3.4	3.1
Maize + *Tephrosia*	2.8	1.3	2.0	1.9	1.8
LSD	0.4	0.5	0.4	0.6	0.5

Scale used for rating: very low = 1, low = 2, high = 3, very high = 4. Technologies were rated independently. Data from five Malawi case study sites with a total of 100 participating farmers. Technologies described in Table 2.
*Groundnut/pigeonpea rotation technology for all locations except the central high-altitude site where soyabean was the short duration grain legume substituted for groundnut, due to the cooler temperatures at the high altitude.

Table 5. Percentage of farmers in case study areas with knowledge concerning recently introduced legumes, and percentage of farmers planning to use these legumes to improve their soil fertility

	Knowledge of legume			Percentage of farmers using		
Household	Pigeonpea	Soyabean	*Tephrosia*	Pigeonpea	Soyabean	*Tephrosia*
Chisepo						
Female-headed	89	100	26	21	5	16
Male-headed	94	95	46	20	8	25
Mangochi						
Female-headed	100	100	45	12	3	9
Male-headed	99	98	41	10	6	14

Data from survey described in Table 3.

The limited amount of land currently devoted to legumes was documented in the survey. As shown in Table 3, about 60% of the land is grown to maize, and about 10% to groundnuts. This is similar to earlier findings on maize-dominated cropping systems in southern Malawi (Shaxson and Tauer, 1992). Other legumes were planted on about 4% of the area, which is a small proportion of land dedicated to legumes. Farmer knowledge of a range of legumes was quite high, over 90% of farmers knew of soyabean and pigeonpea, and almost 40% knew of *Tephrosia* (Table 5). Despite having some knowledge of these legumes, farmers rarely grew legumes with the explicit goal of improving their soil fertility. Only about 7% of farmers considered soyabean as a soil benefiting crop, and 18% knew about the benefits of pigeonpea and *Tephrosia* (Table 5).

Residue management practices currently followed are not conducive to improving soil fertility (Table 6). High quality residues which can ameliorate soils, such as groundnuts and pigeonpea, were managed in the same way as low quality maize residues. This was surprising, as incorporation of legume residues should demonstrate immediate benefits to subsequent crops, whereas maize residues have erratic short-term effects, including possible immobilization of nitrogen and crop growth suppression, and potentially moderate long-term benefits. Yet, all residues were generally managed in a similar fashion, including burning of 50% or more of the residues. Burning is an important management tool for tobacco and cotton, where pests must be destroyed each year, and burning may have some short-term benefits for reducing weed seed in maize-dominated cropping systems (Kumwenda *et al.*, 1997). However, burning contributes significantly to nitrogen and carbon losses from the system, and its use on legume residues could be negating any potential soil benefits from intensification with legumes (Danso, 1992). The rates of burning reported here are higher than those observed at higher rainfall sites in southern Malawi (Kanyama-Phiri *et al.*, 1998).

Taken together the matrix ranking data and the survey indicated that there is a clear opportunity to introduce more legumes into these systems. This is indicated by strong farmer interest in trying new legumes, and legume-intensified systems. It is also important to be aware of the barriers to farmer uptake of these technologies. Barriers highlighted here included labour constraints and lack of information or interest in incorporating legume residues for amelioration of low soil fertility. Future research needs include evaluation of labour requirements for legume-intensified systems, and developing practices and systems which reduce labour inputs, and which enhance farmer understanding of best management practices.

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Table 6. Crop residue management in 1997/98 growing season, average percentage farmers practising each management strategy in Chisepo and Mangochi

	Crop residue type					
Strategy	Pigeonpea	Soyabean	Bean	Groundnut	Maize	Cotton/ tobacco
Livestock	0	5	0	8	1	0
Incorporated early (Apr)	41	15	20	31	34	4
Incorporated late (Sep)	24	5	27	23	23	5
Burn – land preparation	29	10	20	31	28	75
Burn – ash for cooking	0	10	41	8	1	10

Data from survey described in Table 3.

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DISCUSSION

S. Simons. What are the labour requirements for incorporating residues from legumes and green manure into fields? How important is labour as a constraint to adopting these crop technologies?

B. C. G. K. The need for labour occurs during a slack period for the farmer so labour constraints are insignificant. The labour requirement for *Tephrosia* residue management is not high as the plant is cut and the residues incorporated at the same stage as preparing the ridges.

A. J. Sutherland. The message coming from this and other presentations is that a small amount of nitrogen fertilizer (e.g. 20 kg N/ha) is much better than nothing in terms of food produced. What are the implications for the technical messages going out with the starter pack programme?

B. C. G. K. This message coincides well with the starter pack programme. Low rates of the fertilizer provided with the starter packs will much improve yields if the soil has adequate organic matter which in this case would be provided by integrated legume systems. Farmers need to be provided with technical knowledge on the additive effect of legumes to the maize performance.

Integrated Crop Management Research in Malawi: Developing Technologies with Farmers.
Proceedings of the Final Project Workshop, Club Makokola, Mangochi, Malawi, 29 November – 3 December 1999

Initial results from small-scale use of *Tephrosia* and *Crotalaria* in intercropping experiments in Blantyre/Shire Highlands

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ABSTRACT

An intercropping experiment was conducted at 22 farms to investigate the potential use of *Tephrosia vogelii* and *Crotalaria ochroleuca* in restoring soil fertility in Blantyre/Shire Highlands Rural Development Project. This work was conceived because of general low crop production, particularly of maize, in the area due to low soil fertility, and because of the recent escalation in prices of fertilizers. Preliminary field observations in Chiradzulu and Matapwata, on the use of the two crops, revealed that biomass production of around 2000 kg/ha (on dry basis) was possible. In order to work within the existing farming system, a maize-based cropping system with pigeonpea as an intercrop was chosen. Maize is a major staple crop and pigeonpea is a source of protein and so valuable as a food crop but is also a major cash crop in the area. Maize, pigeonpea and *Tephrosia* were planted at the same time but *Crotalaria* was planted beside the ridge at first weeding. Nitrogen fertilizer was applied at the rate of 50 kg N/ha at either maize emergence or 4 weeks after emergence. Maize and pigeonpea were harvested when they were dry. To obtain maximum nitrogen in the biomass, both *Tephrosia* and *Crotalaria* were harvested at peak flowering and the early podding stage. Maize grain yields from early and late fertilizer applications were not significantly different. There was a slight decline in usable maize grain yield ($P = 0.084$) when *Crotalaria* was undersown in maize but *Tephrosia* did not adversely affect the maize grain yields. Biomass production from *Tephrosia* and *Crotalaria* was 1.5–2.5 t and approximately 3.0 t, respectively. Expected benefits and follow-up activities are discussed in this paper in the light of the results of the 1998/99 season. Given the low soil fertility status of the soils in Blantyre/Shire Highlands, fertilizer use is still advocated to give a strong base for crop production.

INTRODUCTION

During the Farming Systems Integrated Pest Management (FSIPM) Project activities in the 1997/98 season, all plots in the main trial under a maize/bean/pigeonpea intercropping system received 50 kg/ha of fertilizer. The fertilizer was applied by dolloping at crop emergence. However, during evaluation interviews, farmers were strongly of the opinion that the timing of the fertilizer application was too early. They felt that early application resulted in a loss of fertilizer through vegetative growth making little contribution to grain production and, therefore, it was wasteful.

As well as the timing of fertilizer application farmers were also concerned at increasing prices of fertilizer. Only a small proportion of farmers can afford fertilizer because of the rising costs (Orr *et al.*, 1997), and significant areas of maize are abandoned after the first weeding if farmers cannot apply fertilizer (Chamango, 1999). Also early modelling work by Orr *et al.* (1998) compared economic benefit from IPM strategies and indicated that improving soil fertility is more beneficial than other strategies. This has resulted in the FSIPM Project focusing attention on the use of green manures as a low-cost approach to increasing soil fertility for stable crop production. Observation plots in Chiradzulu during 1997/98 indicated that 2000 kg/ha biomass can be produced by undersowing maize with *Crotalaria ochroleuca* following the first weeding. The biomass can be incorporated during either *mbwera*, if a winter legume crop is to be planted, or during *kuwojekera*, the first stage of ridging after the maize harvest. The 1996/97 *Striga* trials indicated that a similar level of biomass can also be produced from *Tephrosia* planted at the same time as maize. In this case, the legume is allowed to grow through the dry season prior to incorporation during the final stages of ridge making in September/October.

A small-scale on-farm trial was set up in the 1998/99 season to address the two concerns above, i.e. to study the effects of early and late fertilizer applications and the value of the two green manures to enhance soil fertility and increase maize production. This is essentially a long-term study in which the impact of green manure on maize production would be assessed in the season following incorporation. This paper considers the green manure biomass yield which can be grown, the effect of the green manure intercrop on maize growth and the effect of timing of fertilizer application on maize and green manure yields.

MATERIALS AND METHODS

One researcher-managed trial was set up at 22 farms distributed between Kambuwa and Magomero villages. These were the same sites used in the previous season for a study on the timing of weeding practices and the use of fertilizer (Chamango, 1999). The 22 farm locations represent 11 *dambo* sites and 11 upland sites. The factors investigated were:

timing of fertilizer application:

- early – application at crop emergence
- late – application 4 weeks after crop emergence (farmer practice)

use of green manure:

- *Crotalaria* undersown at first weeding
- *Tephrosia* planted alongside maize
- no green manure grown.

The treatment arrangement is shown in Table 1.

In each farm, either *Crotalaria* or *Tephrosia* was grown in two of the four 'research' plots. *Crotalaria* was planted in six *dambo* and five upland sites. *Tephrosia* was grown in five *dambo* and six upland sites.

One pair of plots in each farm had a late fertilizer application, the remaining pair had an early application. One plot of each pair had a green manure grown within a maize/pigeonpea intercrop. The remaining plot of the pair had no legume. The pair of plots with a late fertilizer application had fertilizer applied in the previous season. The pair with an early fertilizer application had received no fertilizer in the previous season. This confounding would tend to favour the 'late' fertilizer treatment if there was any residual fertilizer effect from 1997/98.

Gross plot size was 5.4 x 5.4 m^2. Net plot sizes for maize, pigeonpea, *Tephrosia* and *Crotalaria* were 3.6 x 3.6 m^2, 3.6 x 2.7 m^2, 3.6 x 4.5 m^2 and 3.6 x 5.4 m^2, respectively. All plots received 50 kg/ha N. Farmers were supplied with fertilizer and seeds of maize, pigeonpea, *Crotalaria* and *Tephrosia* for the trial. Each plot had six ridges with six maize planting stations per ridge (3 seeds/station) spaced at 90 cm intervals. Five pigeonpea stations were placed between the maize stations. *Crotalaria* seed was trickled along a cut line on one side of the ridge; 12 g *Crotalaria* seed/plot were sown beside the ridge. *Tephrosia* was planted at 45 cm intervals on the ridge side between adjoining maize and pigeonpea stations; 5 seeds/station were thinned to 3 seedlings/station after emergence.

Table 1. Arrangement of treatments

1997/98	1998/99	
Fertilizer amount	Fertilizer timing (50 kg N/ha)	Green manure legume
Zero N	Early application	*Crotalaria* or *Tephrosia*
Zero N	Early application	No legume
50 kg N/ha	Late application	*Crotalaria* or *Tephrosia*
50 kg N/ha	Late application	No legume

RESULTS

Analysis of variance (ANOVA) procedures were used to study the effect of fertilizer timing and the use of a green manure on maize yields, pigeonpea yields, *Tephrosia* biomass and *Crotalaria* biomass. The analysis took account of the farmer-to-farmer variation and also investigated the possibility of interactions between the treatment factors and type of farmland (*dambo*/upland). All analyses were conducted using Genstat Release 4.2, Fifth Edition.

Maize harvests

Maize yield responses analysed were usable grain weight (kg/ha), total grain weight (kg/ha), plant height (cm), average cob weight (kg) and the number of cobs per plant. None of these responses showed significant differences across the green manure treatments. However, further analysis revealed some evidence that *Crotalaria* reduced overall and usable grain weight by about 300 kg/ha (P=0.042 and P=0.035, respectively).

Timing of fertilizer application appeared to have no effect on grain yield, average cob weight or the number of cobs per plant. However, plant heights showed strong evidence of a significant difference (P<0.001) between early and late fertilizer application. Maize plants were taller (by about 12 cm) when fertilizer was applied at crop emergence compared with an application 4 weeks after emergence.

Table 2. Mean values for maize harvest responses in the green manure treatment 1998/99

Green manure	Total grain weight (kg/ha)	Usable grain weight (kg/ha)	Plant height (cm)	Average weight of a cob (g)	No. cobs/ plant
None	1958	1650	156	100	0.91
Crotalaria	1660	1354	152	90	0.90
Tephrosia	1865	1554	156	101	0.90
SED	144	137	3.9	6.7	0.038
P	0.101	0.084	0.683	0.293	0.964
Residual df	63	63	63	63	63

Table 3. Mean values for maize harvest responses in the fertilizer timing treatment 1998/99

Timing of fertilizer application	Total grain weight (kg/ha)	Usable grain weight (kg/ha)	Plant height (cm)	Average weight of a cob (g)	No. cobs/ plant
Early	1883	1530	161	99	0.91
Late	1838	1574	149	97	0.90
SED	101	97	2.8	4.7	0.027
P	0.660	0.647	<0.001	0.626	0.645
Residual df	63	63	63	63	63

There was insufficient evidence of a fertilizer timing by green manure interaction. There was also no evidence of an interaction between either of the treatment factors and the type of farmland.

Mean values summarizing results on maize harvests are shown in Table 2 and 3.

Pigeonpea harvests

Five yield responses were analysed with respect to pigeonpea harvests. These were the usable grain weight (kg/ha), total pod weight (kg/ha), plant height, number of seeds in 20 pods and the weight of 100 seeds. Analyses on the first two of these responses showed strong departures from the ANOVA homogeneity of variance assumption. These data were, therefore, transformed to logarithms before further analysis.

Except for the weight of 100 seeds, all other yield responses showed evidence of an interaction between use of green manure and the type of farmland. In addition, plant heights showed significant differences between times of fertilizer application. Late fertilizer application led to pigeonpea plants that were on average about 10 cm taller than those which had an early fertilizer application. There was no evidence that the effect of fertilizer timing varied across the green manure treatment or across the land type.

Results giving mean values for all yield responses, across the green manure treatment factor, are shown in Table 4. The results for usable grain weight and pod weight have been back-transformed to the original scale of measurement in Table 5.

Significantly higher pigeonpea yields were obtained using *Crotalaria* as a green manure in *dambo* areas (P=0.022 and P=0.020 for usable grain weight and pod weights, respectively). However, usable grain weight in the uplands was significantly lower with *Crotalaria* (P=0.040). This reduction was not apparent with respect to pod weights.

Results are reversed when pigeonpea was grown with *Tephrosia*. Pigeonpea yields were significantly reduced (P=0.038 for usable grain yields and P=0.015 for pod weight) with the use of *Tephrosia* in the *dambo*. In the uplands, yields increased with the use of *Tephrosia,* but not significantly.

Neither plant height, nor the number of seeds in 20 pods differed significantly in the *dambo*. In the uplands, use of *Crotalaria* significantly reduced pigeonpea plant height (P=0.003) and produced significantly fewer seeds per pod (P=0.001). *Tephrosia* had no effect on plant height, nor on the number of seeds per pod.

Tephrosia biomass (results of the current trial)

Tephrosia dry leaf biomass (kg/ha) and dry wood biomass (kg/ha) were analysed to study the possible effects of fertilizer timing and to explore a possible interaction between fertilizer timing and type of farmland. The analysis for dry leaf biomass showed significant differences with respect to

Table 4. Mean values for pigeonpea yield responses across the green manure treatment factor 1998/99

Green manure	Log usable grain weight (kg/ha)		Log pod weight (kg/ha)		Plant height (cm)		No. seeds in 20 pods		Weight of 100 seeds (g)*
	Dambo	Upland	*Dambo*	Upland	*Dambo*	Upland	*Dambo*	Upland	
None	4.40	4.30	5.25	5.05	167	179	94	98	17.0
Crotalaria	5.00	3.79	5.90	4.91	160	154	99	85	19.4
Tephrosia	3.92	4.64	4.65	5.37	167	191	93	93	17.0
SED	0.26	0.22	0.27	0.25	9.4	8.3	4.1	3.8	0.98
P manure (averaged over land type)	0.490		0.804		0.673		0.226		0.320
P fertilizer timing	0.258		0.734		0.033		0.365		1.000
P manure × land type	<0.001		0.002		0.042		0.032		0.779
Residual df	46		47		49		46		37

*Averaged over land type.

Table 5. Pigeonpea usable grain weight and pod weight re-transformed to original scale of measurement 1998/99

	Usable grain weight (kg/ha)		Pod weight (kg/ha)	
Green manure	***Dambo***	**Upland**	***Dambo***	**Upland**
None	82	74	191	156
Crotalaria	148	44	365	136
Tephrosia	50	104	105	215

both these effects (P=0.045 and P=0.026, respectively). In *dambo* areas, the biomass was slightly higher with an earlier application of fertilizer (but the difference was non-significant). In the uplands, however, the biomass was considerably higher (P=0.007) with a later fertilizer application (Table 6).

With respect to dry wood biomass, there was no evidence that the effect of fertilizer timing varied across type of farmland. The later fertilizer application gave higher dry wood biomass in both *dambo* and upland fields, but this increase was significant only in the upland (P=0.018). The results are summarized in Table 6.

Tephrosia biomass (from the *Striga* trial)

In the 1997/98 and 1998/99 crop seasons, *Tephrosia* was also used to improve soil fertility in a trial set up to explore strategies for the management of the parasitic weed, *Striga asiatica* (see Chanika *et al.*, p. 216). In these trials, both fertilized and non-fertilized plots were used, as well as an additional green manure, i.e. cowpea, in the 1997/98 season, and two green manures, i.e. cowpea and *Crotalaria* in the 1998/99 season. Results on *Tephrosia* dry leaf and dry wood biomass are shown in Table 7. *Tephrosia* biomass yields were very poor in the 1997/98 season although in the current study *Tephrosia* biomass production was close to 2000 kg/ha. Even in the 1998/99 season, yields are much lower than found in the current study, possibly due to the trial being conducted in *Striga*-infested fields which are characterized by extremely low fertility, particularly in percentage of organic matter and nitrogen, with averages of 1.06% and 0.05%, respectively.

Table 6. Mean values for *Tephrosia* biomass across the fertilizer timing treatment 1998/99

	Dry leaf biomass (kg/ha)		Dry wood biomass (kg/ha)	
Timing of fertilizer application	***Dambo***	**Upland**	***Dambo***	**Upland**
Early	1648	1803	2727	3925
Late	1554	2548	3142	4980
SED	232	212	399	364
P fertilizer timing, averaged over land types	0.045		0.019	
P timing x land type	0.026		0.266	
Residual df	9		9	

Table 7. Mean values for *Tephrosia* biomass from *Striga* trials in the 1997/98 and 1998/99 seasons

	Dry leaf biomass (kg/ha)		Dry wood biomass (kg/ha)	
Timing of fertilizer application	**1997/98**	**1998/99**	**1997/98**	**1998/99**
No fertilizer	140	676	503	1948
Fertilizer applied	106	1025	409	2471
SED	123	118	85	287
P	0.280	0.280	0.301	0.280
Residual df	9		9	

Table 8. Mean values for *Crotalaria* biomass and other parameters in the fertilizer timing treatment

Timing of fertilizer application	**Dry weight biomass (kg/ha)**	**No. pods/ plant**	**No. seeds/ pod**	**Plant height (cm)** *Dambo*	**Upland**
Early	2949	36.0	83.3	172	143
Late	3375	39.2	87.1	156	151
SED	443	6.1	5.3	5.9	6.5
P fertilizer timing, averaged over land types	0.359	0.534	0.481	0.306	
P timing × land type	0.331	0.232	0.946	0.025	
Residual df	9	9	9	9	

Table 9. Mean values for *Crotalaria* biomass and other parameters from results of the 1998/99 *Striga* trial

Application of fertilizer	Dry weight biomass (kg/ha)	No. pods/ plant	No. seeds/ pod	Plant height (cm)
No fertilizer	2090	24.4	76	161
Fertilizer applied	1739	22.0	76	151
SED	350	3.8	4.8	7.2
P	0.334	0.544	0.987	0.175
Residual df	13	13	13	13

Crotalaria biomass (from the current trials)

Four responses were analysed with respect to growth parameters of *Crotalaria*. These were dry weight biomass (kg/ha), number of pods per plant, number of seeds per pod and plant height (cm). The first three of these responses did not display evidence of differences according to the timing of fertilizer application. With respect to *Crotalaria* plant height, there was some evidence of a difference in *dambo* areas where the mean plant height was greater with the early application of fertilizer (P=0.028). There was insufficient evidence of a difference in plant heights in the upland areas. The results are shown in Table 8.

Crotalaria biomass (from the *Striga* trial)

Crotalaria was grown as a green manure in the 1998/99 *Striga* trial. Results concerning *Crotalaria* biomass and other parameters appear in Table 9. As with *Tephrosia*, the biomass and other yield parameters were lower than those found in the current study trial. Addition of fertilizer appeared to depress *Crotalaria* yields slightly but not significantly.

Nematode root scores on *Tephrosia* plants and soil-extracted nematode estimates

In the 1998/99 green manure trial, nematode measurements were made by two separate means. First, a random sample of five *Tephrosia* plants were scored for their nematode damage on a 1–10 scale and the mean value taken. Secondly, root-knot nematode (*Meloidogyne* sp.) juveniles (j_2s) were extracted from the soil using a tray method (Whitehead and Hemming, 1965) and the mean number per millilitre of extraction liquid determined. The latter measurements were taken on all 88 plots included in the trial. They gave only 20 values since they related only to those plots where *Tephrosia* was grown.

Table 10. Means of soil sampled nematodes across treatments in the green manure trial, 1998/99

	Legume			Fertilizer timing	
Nematodes	None	*Crotalaria*	*Tephrosia*	Early	Late
Mean no.	83	117	73	102	72
SED		24		16.7	
P		0.430		0.035	

Soil-extracted nematode mean numbers were subjected to standard (ANOVA) procedures. The results are summarized in Table 10 and show that contrary to expectation, the *Crotalaria* plots showed higher nematode incidence. Mean nematode numbers under *Crotalaria* were higher than those under *Tephrosia* and higher than the mean nematode numbers in plots without a legume, but not significantly (P=0.065 and P=0.101, respectively).

The relationship of both nematode measurements were also studied briefly via scatter plots. A matrix plot showing an absence of a relationship is provided in Figure 1.

DISCUSSION

Timing of fertilizer application

In this experiment fertilizer timing did not affect maize yields, although plants were taller with an early application. However, it is apparent that pigeonpea and *Tephrosia* which develop more slowly, benefit in terms of increased vegetative growth from the later fertilizer application, whereas *Crotalaria*, which matures more rapidly, had a tendency to increased growth with the earlier application. Where long

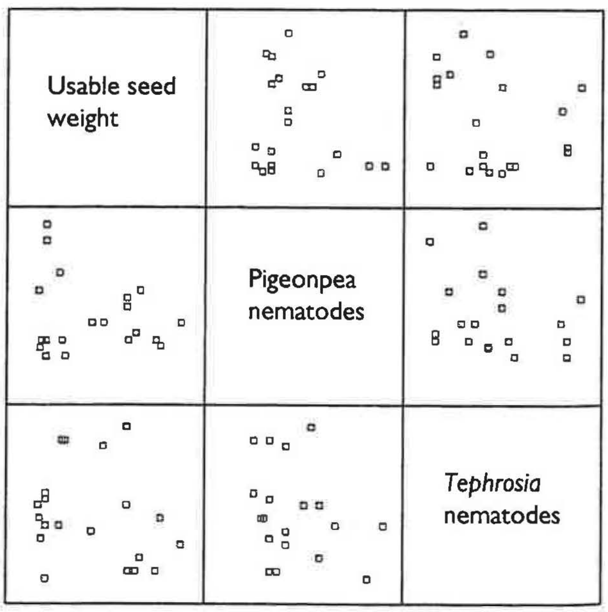

Figure 1. Scatter plot showing relationship of pigeonpea yields and nematode scores, green manure trial, 1998/99.

Table 11. Treatments for future trial

1997/98	1998/99	1999/2001
Zero N	Early fertilizer + *Tephrosia/Crotalaria*	*Tephrosia/Crotalaria* alone
Zero N	Early fertilizer alone	Fertilizer alone (once)
50 kg N/ha	Late fertilizer + *Tephrosia/Crotalaria*	Fertilizer + *Tephrosia/Crotalaria*
50 kg N/ha	Late fertilizer alone	Fertilizer alone (split)
N/A	N/A	External plot (no manure/ fertilizer)

duration intercrops are grown with maize, it would appear that early application does not lead to reduced maize yield and may benefit the maize plant. However, the tall maize plants (12 cm taller) may compete strongly with a legume intercrop, since late application of fertilizer led to pigeonpea plants that were on average about 10 cm taller than those which had an early fertilizer application. Farmers are interested in both the cereal crop and the legumes, either as food crops or cash crops. The decision to apply fertilizer slightly later balances the farmers' needs in that it does not maximize maize yields but it enhances the ability of a legume crop to yield reasonably as competition from maize is minimized. Also, the fertilizer will be used for grain filling instead of boosting vegetative growth.

Competition effects

Tephrosia had no significant adverse effect on maize yield. However, *Crotalaria* did cause slight usable grain yield depression (P=0.084). *Crotalaria* plants grow rapidly and vigorously such that competition for water, light and nutrients could translate into higher grain loss through rotting. Though pigeonpea yields are low in the Matapwata area, there is some trend with respect to the presence of *Crotalaria*. Pigeonpea yields were reduced in the upland area but were increased in the *dambo* area when *Crotalaria* was present. *Dambo* areas have excessive water during the rainy season but have adequate moisture to support a growing pigeonpea crop during dry months. Relatively reduced yields of pigeonpea in the upland area in the presence of *Crotalaria* are probably due to competition for resources, but the increased yields in the *dambo* area might be a result of increased nitrogen from the breakdown of nodules and roots of *Crotalaria* where moisture is adequate to support a growing plant during the dry season. (Other factors could also play a part. It is possible that there is a protective effect. For example, anthelminthic exudates might protect against nematodes or trap cropping may protect against pod borers.) However, the beneficial effect on pigeonpea is evidently not at the expense of the *Crotalaria* biomass yield or seed production.

Expected benefits to smallholders

The real benefits from the green manure experiment be evident in the 1999/2000 season when the effect of incorporating between 1.5 and 2.5 t/ha of *Tephrosia* and around 3 t/ha of *Crotalaria* will be seen in improved maize yields. Incorporating *Tephrosia* increases maize yield by about 30% when 2 t of biomass are produced (Chanika *et al.*, p. 216).

Preliminary observations in Chiradzulu indicated that an additional 500 kg/ha of usable maize yield is obtained when *Crotalaria* is incorporated (averaged across four observation plots: *Crotalaria* + fertilizer produced 2465 kg/ha usable grain yield as against 1880 kg/ha usable grain yield produced from fertilizer alone). *Tephrosia* and *Crotalaria* could be rotated as green manure crops but it will be important to observe the health of the maize and pigeonpea crops to be assured that no adverse effects have ensued due to a build-up of whitegrub and/or nematode.

Follow-up work

This trial is continuing, with some modifications, with funding from another source. Fertilizer will be applied 4 weeks after maize emergence in order to benefit both grain filling and the legume intercrop. Green manures (*Tephrosia* and *Crotalaria*) alone and fertilizer alone, as well as both in combination, will be tested alongside a treatment where neither green manure nor fertilizer has been applied as shown in Table 11.

CONCLUSIONS

As soils in the Blantyre/Shire Highlands are of low fertility, the use of inorganic fertilizers is advocated but at a lower level in order to have a strong crop production base. This will be kept under review as more data become available from the trials. Biomass production from *Tephrosia* and *Crotalaria* is satisfactory and is likely to result in increased maize grain yields in the coming season.

Crotalaria does compete with maize when planted at first weeding but *Tephrosia* does not adversely affect the maize crop.

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DISCUSSION

J. Mapemba. Does the increase in yield due to the combination of *Tephrosia* and fertilizer compensate for the cost of the fertilizer and labour?

C. S. M. C. There are plans to carry out an economic analysis.

B. Msiska. It is interesting to learn about the beneficial effects of legume and agroforestry species on maize production. As Malawi is advocating crop diversification to improve food security, is the scientific sector considering the possible use of legumes and agroforestry species in other important crops, such as cassava and sweet potato?

C. S. M. C. Some work was proposed by the Root and Tuber Crops Commodity Team on the use of agroforestry species for soil fertility improvement in cassava and sweet potato production.

C. R. Riches. A number of groups are moving towards the promotion of green manure technologies. We know that there is considerable heterogeneity in Malawi in terms of soils and farmer resources so perhaps there needs to be careful thought about targeting of technologies. *Crotalaria*, for example, may be of benefit for low productivity maize plots where the farmer cannot afford fertilizer. These sites are sometimes abandoned as yields will be low. In this case something can be gained by undersowing *Crotalaria* to 'add-value' to plots which otherwise may be abandoned.

M. M. Kayembe. When researchers are conducting their activities concerning food security, they should not concentrate on maize only, knowing the variability of ecological conditions. Other crops, such as cassava and sweet potato, should be considered, especially nowadays when the rains are not consistent in distribution.

Factors influencing the adoption of land conserving technologies in Malawi: the Blantyre/Shire Highlands Rural Development Project

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ABSTRACT

Land degradation is high in Malawi with erosion rates at more than double the threshold value. Conservation efforts started as early as 1902. This study was aimed at learning the perceptions of farmers on land degradation and the factors influencing the adoption of soil conserving technologies. Farmers perceive that soil fertility loss is more serious than soil erosion. However, their soil fertility practices are not adequate to maintain a healthy crop up to maturity. It is concluded, therefore, that farmers need technical assistance to explain to them the advantages and limitations of the various soil fertility practices, especially the organic fertility practices, presently being promoted. The study also revealed that although farmers use various erosion control practices, they have serious soil erosion problems. It was found that most of the physical structures that farmers use to control erosion are poorly made and maintained. Since farmers are still experiencing erosion problems, it is concluded that farmers require technical help in constructing physical soil conservation measures. It was found that farmers will adopt soil conserving technologies where they are experiencing high soil erosion, when they have few fields, when their social status is high and when they are not very poor.

INTRODUCTION

Land is one of the most important resources in Malawi because the economy of Malawi is dependent on agriculture. Of the total land area, only 31% is suitable for cultivation at the present level of management, however, about 50% of the land is under cultivation. Thus marginal land and unsuitable land is extensively cultivated (GoM, 1994). When the problems of soil erosion were estimated, it was found that there is a nationwide average soil loss of 20 t/ha annually, which is twice the threshold value (World Bank, 1992). Although there are few references in the literature which establish that land degradation is responsible for the decline in production, the fact remains that Malawi has been experiencing a decline in production. Before 1980, GDP growth rate was positive at 5.8% on average annually (1965–80). However, since 1980, Malawi has been experiencing negative GDP growth. When the cost of land degradation was estimated in 1994, it was established that the cost of soil erosion alone was equivalent to 8.1% of the GDP (GoM, 1994). Thus soil degradation is higher than the annual economic growth rate.

Land conservation efforts started as early as 1902 through the introduction of the Native Reserves. However, land degradation was perceived as being a threat to agricultural production in Malawi as early as the 1930s, during the British Colonial Administration. Geographically Malawi, then Nyasaland, was related to other countries such as China, Java, Korea, Japan, the tropical American regions and the Mediterranean countries. It was found that Malawi was highly vulnerable to erosion similar to Greece or Korea, both of which had experienced heavy soil degradation (Hornby, 1934). The colonial administrators tried to address land degradation in the following ways: introduction of the Native Reserves in 1902; appointment of the first conservation officer in 1936; enactment of the first National Resource Ordinance in 1946; formation of land use schemes, such as Master Farmer Scheme, Smallholder Scheme and Village Land Improvement Scheme in the 1950s; and the establishment of the Mechanical Soil Conservation Unit in 1955 (Mwendera, 1989).

After independence in 1964, the government's efforts towards arresting land degradation were reflected in: the launching of the Lilongwe Land Development Programme in 1968; the creation of the Land Husbandry Branch; and the establishment of the Land Husbandry Training Centre; the National Environmental Action Plan (GoM, 1994); the Environmental Policy (GoM, 1996); and the establishment of various projects and NGOs.

Given the history of conservation, it is worrying that erosion is constantly increasing. A number of reasons have been given for the increasing soil erosion, but the most important is the low adoption of conservation technologies.

Factors affecting adoption of improved technologies

An innovation (technology) is an idea, method or object that is regarded as new by an individual. The process of implementing an innovation is called the adoption process. Research has shown that there is a positive relationship between an individual's adoption index and the following variables: education, literacy, higher social status, large size units, commercial economic orientation, more favourable attitude to change, more favourable attitude to education, intelligence, social participation, cosmopolitanism (urban contacts), change agent contact, mass media exposure, exposure to interpersonal channels, more active information seeking, knowledge of innovations and opinion leadership. Contrary to popular opinion that young people are more innovative than are older people, it is established that age has little influence on the adoption of innovations (Van den Ban and Hawkins, 1996). Diagne *et al.* (1995) reported that risk-bearing ability and access to markets can influence farmers to adopt such crops as hybrid maize and tobacco in Malawi. They also reported that farmers' participation in formal credit schemes depends on economies of scale, sex, household's liquidity and nearness to parents' residences. Smale *et al.* (1991) reported that institutional factors, such as credit availability and input markets, affect the adoption of technologies, but not always, as was the case with the Blantyre farmers. They also reported that adoption of maize technologies depended on agro-ecological zones, sex of the household head, credit club membership and the farm size class. Hassan *et al.* (1998) reported that the adoption of improved maize varieties in Kenya was influenced by such factors as better agro-ecological zones, investments in seed distribution, extension, physical infrastructure, social factors, such as better education, better credit facilities, larger farm holdings, younger age, and male sex.

Van den Ban and Hawkins (1996) reported that research has demonstrated that there are extensive delays between the time the farmer first hears of favourable innovations and the time he takes to adopt them. It took 4 years on average for the majority of mid-western US farmers to adopt recommended practices. Several hypotheses have been developed to explain why some farmers adopt innovations very slowly. The 'individual-blame' hypothesis says that people adopt innovations slowly because of their traditional or conservative attitude towards life. The 'system-blame' hypothesis states that it is not sensible for farmers to adopt ideas when they do not have sufficient resources or when service providers, such as moneylenders, marketers and others, profit from these innovations rather than the farmers. Other reasons could be that innovations are not available in remote areas and inputs are sold in much larger quantities than small farmers can use or afford. Ndiaye and Sofranko (1993) reported that delays in the adoption of soil fertility and soil conservation practices are because the innovations are more demanding and more complex than other types of innovations. They demand more labour, take away land from cropping, and are of questionable value in the eyes of many farmers. They also reported that farmers in Rwanda were failing to adopt conservation measures because they were cultivating many fields, 9–10 fields/farmer.

Population pressure is believed to a major factor influencing land degradation. Ndiaye and Sofranko (1993) reported that in areas of high population densities, environmental problems are becoming much more visible. They reported that problems of soil erosion, farming on highly eroded land, loss of soil fertility, downstream pollution, and deforestation are seen in Rwanda, Malawi and other densely populated areas where cultivable land is dwindling, unlike the less densely populated areas such as Mauritius, Botswana and Chad. The Government of Malawi and United Nations (1993) reported that as land holdings become smaller, multiple and relay cropping practices are becoming more widespread so as to maximize land utilization. These practices were discouraged in the past but their value is now recognized by the extension service. Ramaswamy and Sanders (1992) in Burkina Faso, found that farmers are encouraged to adopt yield increasing intensive technologies as land becomes more limited. Farmers tend to adopt such methods and abandon extensive cultivation of marginal lands.

The problem of low adoption of land conserving technologies needs to be addressed if technologies in land conservation are to be important remedial measures for soil erosion control. The focus of this study was to determine the factors that influence the adoption of conservation practices. This study will, therefore, benefit those organizations which implement conservation projects on farmers' fields by providing some insights towards farmers' perceptions of soil conservation technologies. It will provide these organizations with guideline information necessary for implementing strategies outlined in unit 12 of the Agricultural and Livestock Development Strategy and Action Plan of 1995 and in chapter 5 of the National Environmental Action Plan, (GoM, 1994).

The main objective was to find out why farmers are not readily adopting improved land management practices. This was done by looking at the status of soil fertility and soil conservation practices among smallholder farmers. The specific objectives were:

- i to determine farmers' perceptions of soil fertility and soil erosion problems;
- ii to determine farmers' existing soil fertility and conservation practices;
- iii to determine if the economic benefits of soil conservation are different between arable fields and hill slope fields;
- iv to identify the factors influencing farmers' adoption of soil conservation strategies.

METHODOLOGY

Methods of data collection

Data collection was carried out using three methodologies: interviewing household heads using a structured questionnaire, conducting focus group discussions (FGD), and taking field measurements. Interviews were conducted with the household heads at their houses and the researcher was later taken to the main fields to make observations and take measurements. The main field was the field to which the household gives priority in terms of labour and other inputs when cultivating several fields. After conducting interviews in the village under study, the researcher then conducted one FGD with the villagers. Ndiaye and Sofranko (1993) conducted their study in a similar way. They carried out in-depth informal discussions with farmers, in addition to the formal survey, in order to learn more about the farmers within a limited time.

Study sites and sample

This research was conducted with financial help from the Farming Systems Integrated Pest Management (FSIPM) Project. The research is, therefore, an output of the project and was carried out on project sites. The FSIPM Project sites were Mombezi and Matapwata Extension Planning Areas (EPAs) in Chiradzulu and Thyolo Districts, respectively, in the Blantyre/Shire Highlands Rural Development Project (RDP) located in Blantyre Agricultural Development Division (ADD). Blantyre ADD is one of the eight ADDs in the country. The country is divided into ADDs, RDPs and EPAs based on agro-ecological conditions. Blantyre/Shire Highlands RDP is situated on a plateau of rolling or flat upland plain 600–1200 m above sea level. Rainfall ranges from 800 mm to 1300 mm annually, falling in one continuous rainy season from November to March followed by showers (*chiperoni*) in the cold months from May to July. Soils are mostly deep, well-drained and medium textured but low in plant nutrients (Orr *et al.*, 1997).

The FSIPM Project operated in two of five EPAs. The average population density of these EPAs was 285–290 persons/km^2, the highest in Malawi. The farming system is characterized by intensive cropping of maize with intercrops of pulses and legumes (mainly pigeonpea and bean). Commercialization is driven by demand from urban consumers in Blantyre and Limbe. Other important crops are summer vegetables (cabbage and tomato). In Mombezi EPA, the FSIPM Project site was Chiwinja and Lidala villages of Traditional Authority (TA) Mpama, while in Matapwata EPA, the project site was Kambuwa and Magomero villages of TA Chimaliro. On average, farm size in these sites was 0.7 ha, while the size of household was 4.6 persons (Orr *et al.*, 1997).

Stratified random sampling was used for the interviews with a structured questionnaire. Lidala village in Mombezi and Magomero village in Matapwata, with a total of 276 households, have largely hill slope landscape. These two villages made up one stratum. Chiwinja village and Kambuwa village, again in Mombezi and Matapwata, respectively, with a total of 396 households, are on flat land with slopes less than 12° (arable), and these two made the other stratum. The total population for the study area was 672 households. To determine sampling frames for the two strata, maps of the villages were drawn and households were located on the maps, which were then listed for sampling. The two sampling frames were used to draw the surveyed farmers according to the sampling design. A total of 60 farmers was then randomly selected, half of which was selected from farmers that had hill slope gardens. It was assumed that there was higher heterogeneity amongst hill slope farmers, hence a slightly larger sampling ratio on farmers cultivating on hill slopes was allowed.

Models

Logit regression analysis was used for the analysis. Two logit models were run – adoption and willingness to adopt. The dependent variable in the first logit (adoption = WLI) was equal to 1 if the household had some conservation measures in the main field, and 0 if it had not. The dependent variable in the second logit (willingness to adopt = WLI2) was 1 if the household was willing to put more effective measures of conservation in the main field, and 0 if it was not willing. The dependent variables are dichotomous variables since they only take the values of 1 or 0. When a dependent variable is dichotomous the standard ordinary least squares OLS regression cannot be used because the assumptions made about the error term are violated. The common models used for this type of regression analysis include the linear probability model, the probit model and the logit model. The linear probability model has the drawback that the predicted values can fall outside the permissible interval (0,1). The difference between the probit and the logit models is in the assumptions made about the error term. If the error term has a logistic distribution, we have the logit model. If it has a normal distribution, we have the probit model. The results are usually similar, and it is unlikely that very different results using the logit or the probit model will be obtained unless the samples are large because the logistic and the normal (cumulative) distributions are close to each other except at the tails. If both models are computed, one should make some adjustments in the coefficients to make them comparable (Gujarati, 1988; Maddala, 1988).

The logit model

The model of adoption will be used for the purpose of explaining the logit model. A similar explanation would be used for the second logit model, i.e. willingness to adopt.

The dependent variable, adoption = *a*, is dichotomous:

$a = 1$ means the household has adopted conservation measures

0 means it has not.

The probability that the household has conservation measures given a set of determining factors is:

$$P_i = E(a = 1X_i) = 1 / [1+e^{-(b1+b2Xi)}] \qquad (1)$$

where P_i = probability that the household has conservation measures; $E(a = 1X_i)$ = the conditional expectation that a = 1 given X_i; (a = 1) = the household has conservation measures; X_i = set of determining factors; e = base of natural logarithm; b_1 = constant term; and b_2 = slope coefficient.

Equation (1) can be simplified into

$$P_i = \quad 1 / (1+e^{-Zi}) \qquad (2)$$

where $Z_i = b_1 + b_2X_i$

Equation (2) represents what is known as the *logistic (cumulative) distribution function* (Gujarati, 1988). If P_i is the probability that the household has adopted some conservation measures, the probability that the household has not adopted any conservation measures is $(1-P_i)$ which is:

$$(1-P_i) = 1 / (1+e^{Z_i})$$

Therefore, we can write

$$P_i / (1-P_i) = (1+e^{Z_i}) / (1+e^{-Z_i}) \quad (3)$$

Equation (3) is simply the *odds ratio* in favour of having conservation measures (the ratio of the probability that the household has adopted some conservation measures to the probability that it has not adopted any conservation measure). If we take the natural log of equation (3) we obtain the log of odds ratio

$$L_i = \ln (P_i / 1-P_i) = Z_i = b_1 + b_2X_i \quad (4)$$

L_i, the log of the odds ratio, is linear in both factors of adoption (X_i) and parameters (b). L_i is called the *logit* and hence this is the *logit model* (Gujarati, 1988).

For estimation purposes the logit is written as

$$L_i = \ln [P_i/(1-P_i)] = b_1 + b_2X_i + u_i \quad (5)$$

where u_i = the error term.

Two logit models were specified. These are logit models for adoption and logit model for willingness to adopt.

- Adoption (WLI) = $L_i = \ln[P_i/(1-P_i)] = b_1 + b_2X_i + u_i$
- Willingness to adopt (WLI_2) = $L_i' = \ln[P_i'/(1-P_i')] = b_1' + b_2'X_i' + u_i'$

where the sign (′) is used to differentiate specifications of the model of willingness to adopt from the adoption model. In both cases, however,

WLI or WLI2 = $f(X_1 \ldots X_{13})$

The set of determining factors X_i was

$$X_i = (X_1 \ldots X_{13})$$

where

X_1 = (AGE): age of the household head; this was a numerical variable

X_2 = (SEX): sex of the household head; dummy for sex (0 = female, 1 = male)

X_3 = (EDUCTN) Educational level of the household head, categories of formal education;

1 = std 1–4

2 = std 5–8 and adult literacy

3 = forms 1 and 2

4 = forms 3 and 4,

5 = above secondary education

X_4 = (SOCIST): social status of the household head, responsibilities held in the village, level of responsibility in the community

0 = no community responsibility

1 = committee member in any communal responsibilities

2 = executive responsibilities (chairman, secretary, treasurer, etc.)

3 = local administrative responsibility (village headman, chief, etc.)

X_5 = (ECONOM): economic status of the household, a weighted average of farming activities, other income generating activities, and food security

1 = very poor household

2 = poor household

3 = average household

4 = slightly above average household,

5 = rich household

X_6 = (TOTLAB): total labour in the household (calculated man units of labour)

1 = <1.0 man units of labour

2 = 1.0–2.9

3 = 3.0–4.9

4 = >5.0

X_7 = (FILDSZ): size of the main field, continuous variable

X_8 = (FERTMN): fertility of the main field in three levels

1 = poor

2 = slightly rich

3 = very rich

X_9 = (SLOPE): slope of the main field in degrees, an average for the field, also continuous variable

X_{10} = (ERFDME): erosion level observed in the main field

X_{11} = (NUMFIED): number of fields the household has, number of different land fragments, continuous variable

X_{12} = (LNDSZ): total land area available to the household, an approximation of the areas of all land fragments, continuous variable

X_{13} = (EXLATE): dummy for extension education

0 = learnt no land technologies from extension workers

1 = learnt some form of land technologies from extension workers

RESULTS

History of the study area

The history of all the villages in the study area dates from 1890 and the early 1900s (see Table 1). All these villages started when the village headmen's parents or ancestors through the maternal line settled in the respective areas. At that time land was not limited, hence they practised shifting

Table 1. History of the study villages

History	Villages on arable land		Villages with hill slope fields	
	Chiwinja	Kambuwa	Lidala	Magomero
Year established	1908	1901	1915	1890
First inhabitants	Chief's grandmother	Chief's family: the Kambuwas	Chief's grandfather	Chief's great uncle
Fertile soils	Whole village	Whole village	Whole village	Whole village
Soil erosion	None	None	None	None

cultivation as a soil fertility practice. Farmers could not identify places that were not fertile in the early 1900s, it was argued that all land was fertile at that time. It was also argued that since land was not limited and farmers practised shifting cultivation, conservation was not necessary.

Soil fertility management practices

The soil fertility practices that farmers used included burying crop residues after harvest, the application of fertilizers, use of legumes, and manure applications. All the respondents said that they practised burying residues to conserve soil fertility. They said that the practice was insignificant in improving soil fertility but that it helped in making the plants respond more positively to other inputs. It was alleged that if a maize crop was grown in such a field, for example, where no other fertility inputs had been used except the buried residues, the crop would only show a healthy growth when young. After this, it would start yellowing and would not produce any cobs. The second most common fertility practice was the application of fertilizer. Most farmers only applied top dressing fertilizers, not basal dressing fertilizers. While about 58% of the respondents had applied top dressing fertilizers, only about 5% had applied basal dressing fertilizer. It was again found that farmers were not able to acquire adequate fertilizers even for top dressing. Less than 20% of the respondents applied fertilizers to the whole main field but most of them did not manage to apply to even 50% of their main fields. Given that the respondents had more than one field, it was clear that most of their crops did not receive any fertilizer. Other practices like compost manure, animal manure, legume rotation or relay cropping were not common. They were used by less than 10% of the respondents. While most farmers grew some legumes, they said that they were not growing them for enhancing soil fertility (nitrogen-fixation), but for food. Only 5% of the respondents said they used legumes for improving soil fertility. The fertility practices used with legumes were relaying peas after maize, intercropping soyabean or groundnut with maize or growing velvet bean (*kalongonda*). When soil fertility practices were tested for significance, it was found that the soil fertility practices that the farmers used were not significantly related to the health status of the crops. They were not significant even at 10% level of significance.

Table 2 shows that both unhealthy and healthy crops followed the same distribution pattern regardless of the soil fertility practices. The Levene's test of equality between healthy and unhealthy plants was not significant, P=0.116, and the t-statistic was significant at a=0.34. Thus we cannot rule out equality in crop health given the prevailing fertility practices, hence suggesting that the fertility practices the farmers used made no significant contribution to the health status of the crops. The respondents who had healthy crops were respondents whose fields were fertile and more so when the main fields were on hill slopes.

Table 3 shows that crop health was dependent on the status of soil fertility. When the difference in crop health was tested against soil fertility, it was found that the Levene's test for equality was P=0.001 and the t-statistic was also significant at 1% level. Thus the health status of the crops was found to be highly dependent on the fertility status of the soil and not on the fertility practices of farmers. It was also found that the same types of crops were grown in all areas regardless of soil fertility. In the FGD, farmers emphasized that they wanted fertilizers to be more widely distributed by the government. They said that farming without fertilizers was useless. It was also argued that the other fertility practices have many disadvantages, such as the requirement for supplementary fertility practices, and land limitation in the case of crop rotation and manure application. The anticipated yield increases given adequate land management were as much as 300% or more of the present yields.

Table 2. Crop health by fertility practices

Fertility practice	Health status of crop: Not healthy	Very healthy	Row total
Burying residues only	10	7	17 (28.3)
Legume rotation or intercropping	2	1	3 (5.0)
Manure/fertilizer	1		1 (1.7)
Fertilizer	8	12	20 (33.3)
Mixture of any three or more above	9	10	19 (31.7)
Total	30 (50.0)	30 (50.00)	60 (100.0)

Table 3. Crop health by soil fertility

Soil fertility status	Crop health: Not healthy	Very healthy	Row total
Poor	14	2	16 (26.7)
Slightly rich	13	11	24 (40.0)
Very rich	3	17	20 (33.3)
Total	30 (50.0)	30 (50.0)	60 (100.0)

Table 4. The problem of soil erosion

Village	Problem of soil erosion	Causes of soil erosion problem	Worst-affected areas	Introduction of conservation technologies	Perceptions
Chiwinja	Increasing erosion	Deforestation, destruction of old conservation structures	*Dambos*	1950s waterways, check dams, box ridges, contour and graded bunds	*Dambos* and other low lands are worst hit by erosion because of cumulative run-off. Erosion control should be under local leadership to be effective.
Kambuwa	Increasing erosion	Deforestation, and run-off from roads	Low lands	1950s waterways, contour and graded bunds.	Soil erosion is not a general problem but is specific to a few individual farmers.
Lidala	Increasing erosion	Deforestation, destruction of structures built in 1950s, hill slope cultivation	Hill slopes	1950s waterways, box ridges, contour and graded bunds	Traditional bunds are failing to contain erosion.
Magomero	Increasing erosion	Deforestation, hill slope cultivation, uncontrolled run-off from hills and roads	Low land below the hills	1950s waterways, contour and graded bunds, 1990s contour ridges on hills	Use of casual labour and mice hunters destroy conservation structures.

Soil erosion management practices

In the FGDs, farmers also said they had erosion problems. Table 4 shows that all the four villages have an increasing erosion problem. The causes of this problem were deforestation, cultivation on steep slopes, run-off from roads and destruction of old conservation structures. The worst-affected areas are the low lands receiving run-off from adjacent cultivated hills. Farmers said that before colonial administration they had no soil erosion problems. They had plenty of land and practised shifting cultivation. However, they were forced by the colonial administration to stop practising shifting cultivation, to stop cultivating on marginal lands, hill slopes or on riverbanks, and to build conservation structures on their land. Conservation structures were built on arable land (land of less than 12°) in all the four villages by the late 1950s. The structures included contour ridges, contour bunds, graded bunds, artificial waterways, check dams, gully control and box ridges. The conservation efforts were, however, frustrated by the fight against colonialism in the late 1950s and early 1960s when farmers destroyed these structures as a form of demonstration. After the colonial administration, the second conservation campaign phase took place in the late 1980s to early 1990s. During this campaign contour bunds were constructed on cultivated steep slopes. Out of the four villages, only Magomero village in Matapwata EPA benefited from this campaign. In Magomero, a government land husbandry assistant aided farmers on hill slopes to construct marker ridges in the early 1990s, which can still be seen.

Table 5. Levels of erosion observed by topography

Erosion in the field		Topography		
Main group	Smaller rating	Arable field	Hill slope field	Row total
Low erosion	None	2	1	3 (5.0)
	Small and few sheets >3 size up to >2 m^2	4		4 (6.8)
	Medium sheet 2–4 m^2 or few rills <30 cm deep	5	3	8 (13.6)
Serious erosion	Medium and few rills 30–40 cm deep	5	1	6 (10.0)
	Few gullies 60–90 cm deep <60 cm wide	2		2 (3.4)
	Ext sheet and a few developing gullies	6	2	8 (13.6)
Very serious erosion	Many well developed rills	3	7	10 (16.9)
	Rills and some developing gullies	2	7	9 (15.3)
	Extensive gulling, well developed	1	9	10 (16.9)
Total		30 (50.0)	30 (50.0)	60 (100.0)

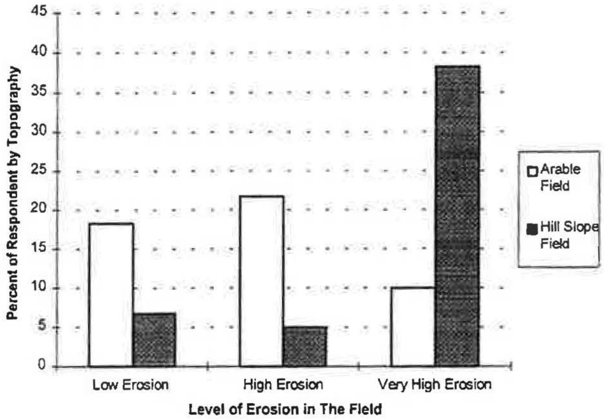

Figure 1. Observed levels of erosion against topography.

Farmers perceive that *dambos* and other low lands are worst affected by erosion because of cumulative run-off from steep slopes. Erosion control should be under local leadership to be effective because run-off starting from other people's fields further up the slope will have adverse effects farther down the slope, hence conservation should be practised communally and under local administration. Soil erosion is not a general problem but is specific to a few individual farmers. Traditional bunds are failing to contain erosion. The use of casual labour and mice hunters is perceived to destroy conservation structures.

Table 5 shows that there were serious erosion problems in the study area. It shows that relatively more farmers that cultivated on arable land had serious erosion problems while farmers that cultivated on steep slopes had very serious erosion problems. These data were plotted and the results are shown in Figure 1. This figure shows that overall about 75% of the respondents have high to very high erosion problems in their fields, about 48% of respondents had a very high erosion problem, and 25% had low erosion. Considering only those on hill slopes, it can be seen that 75% of them had very high erosion and up to 85% [(38+5)/50] of them had high and very high erosion. The adopted erosion control practices included traditional bunds, contour bunds, gully checks, box ridges and some storm drains. Most farmers (about 57%) used traditional bunds which they had constructed themselves. A few farmers (less than 15%) had non-indigenous measures, such as storm drains and contour bunds, which were constructed with the help of the land husbandry assistants. When asked if they were willing to implement more erosion control measures, about 77% of the respondents were willing and almost all said they wanted non-indigenous erosion control measures.

Returns of soil erosion control

The rates of returns to erosion control were determined by asking farmers how much of their yield they lose to erosion and how much more yield they would expect given improved land management technologies. It was found that erosion control is more important to farmers cultivating on steep slopes than to farmers who cultivate arable land.

Table 6. Yield loss to erosion against topography

Topography	Yield loss to erosion NS <1.5	Significant >1.5	Row total
Arable field	26	4	30 (50.0)
Hill slope field	13	17	30 (50.0)
Total	39 (65.0)	21 (35.0)	60 (100.0)

Table 6 shows the amount of yield that is lost due to soil erosion. This was rated as significant if it exceeded 2 bags of 90 kg, hence the 'significant' and 'not significant' terms that are used. About 35% of farmers indicated that soil erosion led to significant yield losses. Most of those who observed significant yield losses had fields on steep slopes. When the difference in yield loss was tested for significance, it was found to be significant at 1% level. This prompted analysis of anticipated yield increases by erosion levels and the results are given in Figure 2. Note that farmers when asked to estimate anticipated yield increases given full land improvements, they estimated increases up to 300% of their present yield.

Figure 2 shows that the percentage of farmers who felt that land improvement would lead to high and very high increases in yield (about three times the current yield) increased with increasing levels of soil erosion. These yield increases were mainly attributed to fertility improvement, however, by plotting against erosion levels, it was found that there was a positive relationship between anticipated yield increases and the levels of erosion. Thus both Table 6 and Figure 2 show that erosion control has a positive rate of return.

Factors influencing adoption of soil conservation techniques

Logit model for adoption of erosion control measures

A total of 14 factors were tested for significance in the adoption of erosion control measures, however, only five factors were found to be significant. These are age of the farmer, sex of the farmer, social status of the farmer, size of the field and the level of erosion in the field (Table 7).

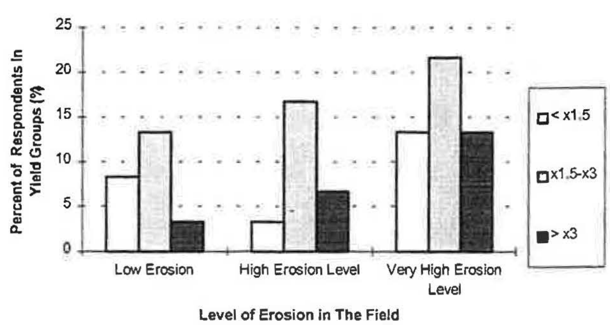

Figure 2. Anticipated yield increase against level of erosion.

Table 7. Parameter estimates – LOGIT model: log[*P*/(1–*P*)] = (intercept + *BX*)

Parameter	Regression coefficient	SE	Coeff./SE
AGE	0.24836	0.14387	1.72632**
SEX	0.38433	0.26192	1.46737*
EDUCTN	0.03687	0.09102	0.40513
SOCIST	0.14023	0.06863	2.04316**
ECONOM	0.01583	0.03681	0.43006
TOTLAB	0.03873	0.05552	0.69761
FILDSZ	0.11652	0.04955	2.35166***
FERTMN	0.39597	0.65794	0.60184
SLOPE	0.00687	0.00781	0.87964
ERFDME	0.31156	0.09249	3.36876***
NUMFIED	–0.02183	0.06886	–0.31698
LNDSZ	–0.09047	0.13202	–0.68528
EXLATE	0.06137	0.07119	0.86200
	Intercept	**SE**	**Intercept/SE**
	–5.88093	0.76568	–7.68066***

Pearson goodness-of-fit chi square = 60.915; DF = 46; $P = 0.069$
*, ** and *** show level of significance at 10, 5 and 1%, respectively.

Table 8. Parameter estimates – LOGIT model: log[*P*/(1–*P*)] = (intercept + *BX*)

Parameter	Regression coefficient	SE	Coeff./SE
AGE	–0.14086	0.93616	–0.15047
SEX	–0.12904	0.26184	–0.49282
EDUCTN	0.34238	0.52657	0.65021
SOCIST	2.01416	0.97342	2.06916**
ECONOM	0.16317	0.12532	1.30203*
TOTLAB	0.37441	0.49022	0.76376
FILDSZ	0.07624	0.08520	0.89484
FERTMN	0.63363	0.49915	1.26938*
SLOPE	0.10805	0.75804	0.14254
ERFDME	1.74243	0.89625	1.94413**
NUMFIED	–0.09616	0.87276	–0.11005
LNDSZ	–0.01477	0.01423	–1.38932*
EXLATE	0.01480	0.02246	0.65895
	Intercept	**SE**	**Intercept/SE**
	2.97293	0.92201	3.22441***

Pearson goodness-of-fit chi square = 89.440; DF = 46; $P = 0.000$.
*, ** and *** show level of significance at 10, 5 and 1%, respectively.

Sex of the farmer factor shows that more male farmers have adopted erosion control measure than female farmers. Age shows that more elderly farmers have adopted than younger farmers. The more responsible a farmer is in the community (social status) the more likely he is to have some conservation measures. It was also found that conservation measures are more likely to be implemented in larger fields than in smaller fields, and having many fields adversely affects adoption of soil conservation. Lastly, the higher the level of erosion in the field, the higher is the level of adoption of erosion control. The most significant factors are levels of erosion in the field and size of the field. These are significant at 1% while the other factors mentioned above are significant at 5%. Sex of the household head is significant at 10%. All the other coefficients are not significant at 10% level. However, it should be pointed out that the number of fields and the total land area have a negative influence on the adoption of erosion control measures. The goodness-of-fit chi-square value is significant (P=0.069), showing that the model is not fitted well at 5% level and 10% level of significance.

Logit of willingness to adopt more effective erosion control measures

Factors for willingness to adopt differ slightly to the factors for adoption. The significant factors included social status of the household head, economic status of the household head, fertility level of the field, the level of erosion in the field, and total land size (Table 8).

The more social responsibility the farmer has, and the higher the level of erosion in the field, the higher is the farmer's willingness to adopt more effective erosion control measures. It was also found that the more fertile the field, the more willing the farmer is to build more effective erosion control structures. Farmers who are well off are more willing to adopt more erosion control than poorer farmers. Lastly the more total land that the farmer has, by adding the various pieces of land, the less willing he is to adopt erosion control measures. Social status of the farmer and level of erosion in the field were more significant than the other significant factors. They were significant at 5% level while the other factors were significant at 10% level. All the other coefficients are not significant at 10% level. It again should be pointed out that the number of fields that the farmer has, age of the household head, sex of the household head and total land holding size of the household, have negative coefficients. The goodness-of-fit chi-square value is highly significant (P=000) showing that the model is fitted adequately.

CONCLUSIONS

Farmers regard soil fertility loss and soil erosion as important problems. More farmers felt that soil fertility is more important than soil erosion. However, soil erosion was found to be important to many farmers since they were using various erosion control measures. Farmers also perceive that the rates of erosion are increasing and they are looking forward to receiving assistance in constructing more effective conservation measures than those they are currently using. Therefore, we reject the hypothesis that 'Farmers perceive that soil fertility loss is important but soil erosion is not' and conclude that both are important.

Farmers use various land management practices. It was found that both soil fertility and erosion control practices were inadequate to stabilize the soil in their respective terms. For soil fertility improvement, the most common practices were burying crop residues after harvest and the application of inorganic fertilizer, while organic manure and leguminous crops were not widely used for improving fertility. In terms of yield improvements, many farmers were obtaining very low yields in comparison to their anticipated yields if the land was improved with good land management practices. Hence farmers asked for more accessibility to inorganic fertilizers. On the other hand, the practices that they were using for erosion control included traditional bunds, contour bunds, storm drains, box ridges and stones or plants like bananas to check gully formation. The most common erosion control practice was the use of traditional bunds. It was found that most farmers had serious erosion problems in their fields although they had implemented some erosion control practices.

It is also concluded that erosion control has a positive rate of return since soil erosion leads to significant yield loss and anticipated yield increases given improved land management practices are positively related to erosion control. Erosion control has a higher rate of return to farmers on hill slopes than to farmers on arable land.

Lastly, factors that influence the adoption of soil conservation strategies include: level of erosion in the field, size of the field, social status of the farmer, economic status of the farmer, slope of the field, and total land size. These factors are for both adoption (techniques as seen in the fields) and for the willingness to adopt better conservation measures. The most important variable is the level of erosion; it is very significant to both willingness to adopt and adoption. Since many farmers were willing to adopt erosion control measures but there have been conservation campaigns, it is concluded that farmers will adopt soil conservation techniques given adequate information.

RECOMMENDATIONS

Most erosion control measures are not suitable for steep slopes and adjacent low lying areas. It is recommended that suitable or site-specific physical conservation measures should be considered to sustain the productivity of such areas.

Farmers feel that erosion control, in the colonial era, was effective due to close monitoring in the construction and maintenance processes. It is recommended that monitoring programmes should be considered for effective and sustained soil conservation.

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DISCUSSION

B. Msiska. What methodology did you apply to be able to get information dating as far back as 1900? Even in the early 1900s, farmers claim that they used to shift from one portion of land to another when the first portion was exhausted. Does this not mean that there was a fertility problem but because of the low population density they were able to practise shifting cultivation which is not possible nowadays?

F. M. T. G. I asked the village headmen to select villagers who knew the history of the village and its activities to be part of the focus group discussions. Farmers claim that the land is now completely infertile due to continuous cultivation while in the past they had no soil fertility problem because they could shift to new land. Thus in the past soil exhaustion was a temporal problem.

E. Chilembwe. The presenter has to be very specific about which control measures do not work on hill slopes. I know that there are several technologies that do work, for example, vetiver grass, A-frame, and contour bunds. Hence do not generalize, specify which control measures work in the different areas.

F. M. T. G. The extension service is now targeting the farmer with vetiver grass and contour ridges. It is constructing marker ridges even on hill slopes which farmers expand into contour bunds. These techniques are not effective when the extension service loses focus on how specific one field is from the next. The extension service should recommend to the farmer site-specific measures where necessary.

B. Mwale. Which technologies were farmers willing to adopt? Evidence is that returns to soil erosion control strategies are long term. Farmers look for immediate benefits. This is a strong economic factor affecting the adoption of soil conservation technologies.

F. M. T. G. Farmers were asking for more effective extension-recommended techniques in preference to their present techniques and were willing to replace the old ones where they are failing. Social economic factors were actually regressed where farmers were willing to implement modern techniques in their fields.

R. J. Chapweteka. According to your text there was a sudden and tremendous decline in GDP growth in 1980/81 from 5.8% to negative growth rate (if we convert the cost of soil loss into GDP). What was the main cause of this soil loss in one year which can be translated into something in excess of 13% loss of GDP?

F. M. T. G. I am sorry I did not mean the decline to appear so sudden. The years before and after 1980 take into account the continuous trend from decline to negative. However the negative 8.1% was documented in 1994 and not 1980.

An agronomic and financial analysis of undersowing with *Tephrosia vogelii* and maize in Malawi

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ABSTRACT

Two undersowing trials with *Tephrosia vogelii* and maize were analysed. The first evaluated third season results of 56 farmer-managed sites where undersowing with a fallow season under reduced tillage was compared with continuous maize cultivation under conventional and reduced tillage. Sites were typical of smallholder farms with moderately to severely degraded soils. In scenarios with and without fertilizer, yield and gross margin returns of undersowing were better than sole maize under both conventional and reduced tillage. Undersowing without fertilizer increased yields by 50% and 100% over sole maize under conventional and reduced tillage, respectively. However, a cost-benefit analysis shows that undersowing with a fallow season is recommended only with fertilizer due to the loss of production in the fallow phase unless this land is not planned for cultivation. Sole maize under reduced tillage gave lower yield and financial returns than conventional ridging. This result was probably due to the degraded low organic content of soils which limits the rooting depth of crops when not tilled. The second trial analysed the second season results of an annual system of undersowing which showed highly beneficial yield and financial returns in comparison with sole-cropped maize with and without N fertilizer.

INTRODUCTION

This paper presents an agronomic and financial analysis of two separate trials on undersowing with *Tephrosia vogelii*. The first trial includes data collected from 56 farmer-managed sites across the country (Bunderson *et al.*, 1996). The other is a replicated trial managed by extension staff in Dedza Hills. Details of each trial are presented below.

SITE LOCATION AND TRIAL DESIGN

Trial 1: agroforestry – reduced tillage trial/ demonstrations

A multi-locational 5-year trial was initiated in the 1996/97 season to demonstrate specific agroforestry and soil conservation practices to farmers in Malawi, and to evaluate a system of reduced tillage against the standard practice of ridging with hand hoes. Treatments of relevance to this paper are described below.

Continuous maize – conventional ridging with hand hoes

These plots served as a control for comparing reduced tillage practices. Conventional tillage involves cultivating maize each year on contour ridges built with hand hoes 90 cm apart. This is the common method of land preparation among smallholders in Malawi. It involves an enormous amount of manual labour, and there is evidence that it contributes to soil erosion and declining fertility, particularly under conditions of continuous cereal cultivation with low inputs. Moving the soil accelerates oxidation of organic carbon from the soil. Lack of organic carbon to bind soil aggregates means that soils are more exposed to raindrop action and erosion. Turning the soil also disrupts natural aeration and the beneficial actions of soil microflora and microfauna.

Continuous maize in planting holes with no ridging

These plots involve cultivating maize each year under reduced tillage. The concept is to minimize damage caused by annual deep tilling of the soil, as well as to reduce the labour of ridging. Ridging was carried out in the normal way for the first year. Thereafter, no further ridging was performed, but holes were dug to a depth of 20 cm immediately after the first year's harvest to break through the hard crust of the soil surface. Each hole corresponded to the location of planting stations. Digging holes to this depth was a one-time activity, as the beneficial actions of reduced tillage with stronger root systems of crops grown were expected to maintain good soil structure and permeability. Crop residues were left on the soil surface as mulch and to increase the organic matter content of the soil. The same planting stations were used each year. Five light weedings were carried out during the growing season to reduce disturbance to the soil and to eliminate weed competition.

Undersowing Tephrosia vogelii *with maize under reduced tillage with a second season fallow*

This practice involves undersowing *Tephrosia* with maize in year 1 with normal ridging. Sowing involved two stations of *Tephrosia* between maize stations on every ridge at three seeds per station, 2 cm deep. In year 2, *Tephrosia* was left as a fallow with no tillage. It was then cut down just before the onset of year 3. Leaf biomass was left on the soil surface and stems were removed for fuelwood. Thereafter, maize was cultivated under the system of reduced tillage described above. *Tephrosia* will be undersown again at the start of year 5 to repeat the cycle. The rationale for undersowing with a fallow season is that recent evidence from different land-use surveys in Malawi indicates considerably more fallow or idle land in the smallholder sector than originally thought (Hayes, 1999; Berger, personal communication). Much of this land has either been abandoned due to over-cultivation, or households lack the ability to cultivate their entire land holdings. This presents a unique opportunity to restore these degraded or little-used lands to productive use by introducing a simple, low-input, short-term fallow.

This practice has shown excellent results in Malawi and neighbouring Zambia under both on-station and on-farm conditions. It involves intercropping maize in the first year with fast-growing, N-fixing shrubs such as *T. vogelii*. In the second season cultivation is abandoned, allowing the tree fallow to mature. At the onset of the third season the trees are cut down at ground level, leaving the root and leaf biomass to decompose *in situ*. Bare branches may be removed for firewood or other uses. Cropping is then resumed for 2 years, relying on the improved fertility status of the soil. One concern is that *Tephrosia* is prone to nematodes, which may introduce problems if tobacco or other susceptible crops are grown on the same land. Another concern is the loss of land for one out of four years. It is contended that such losses will be compensated by gains in crop productivity and income from seed harvests.

The trials were established and managed by smallholder farmers in all eight Agricultural Development Divisions (ADD), with supervision from extension staff. Sites represent typical soil and farm management conditions to reflect accurately how the practices discussed operate in the real world of the Malawi smallholder. Each farmer had an unreplicated set of 10 x 10 m plots for the different elements under demonstration. Sites were split to evaluate the effect of fertilizer application on the different practices, giving a total of six comparisons, which were analysed across sites:

- continuous maize grown under conventional tillage, no fertilizer
- continuous maize under conventional tillage, with fertilizer (see rates below)
- continuous maize under reduced tillage + retention of crop residues, no fertilizer
- continuous maize under reduced tillage + retention of crop residues, with fertilizer
- undersowing *Tephrosia* and maize under reduced tillage in year 1, no fertilizer, fallow in year 2, sole maize in year 3 with reduced tillage, no fertilizer
- undersowing *Tephrosia* and maize under reduced tillage in year 1, with fertilizer, fallow in year 2, sole maize in year 3 under reduced tillage, with fertilizer.

Rates of fertilizer used per hectare for all fertilizer treatments are as follows:

- years 1 and 2: Super D + CAN for a total of 47 kg N, 54 kg P_2O_5, 45 kg K, 13 kg S, 0.2 kg B
- year 3: CAN at the rate of 46 kg N.

Trial 2: Dedza Hills annual undersowing

This trial is located in the grounds of the Dedza Hills Residential Training Center where it was managed by extension staff from the Department of Land Resources Conservation with supervision from MAFE officers. The trial was laid out as a randomized block design with plots measuring 10 x 10 m in four replications of five treatments each:

- continuous maize, no fertilizer
- annual undersowing of *Tephrosia* and maize, with no fertilizer
- undersowing of *Tephrosia* and maize in year 1, left fallow in year 2, then maize cultivation resumes in years 3 and 4 without *Tephrosia*
- continuous maize with CAN at the rate of 96 kg N/ha
- annual undersowing of *Tephrosia* and maize with CAN at the rate of 48 kg N/ha.

The trial has just completed its first season after the establishment year. Results presented on maize yields therefore exclude the continuous maize with CAN treatment because it was in its fallow season.

AGRONOMIC RESULTS

Trial 1: agroforestry – reduced tillage trial/ demonstrations

Table 1 shows the third season maize yields from this trial. A sample of 21 sites was used to determine biomass yields of *Tephrosia* at the time of harvest, just before the rains. The average stem and leaf biomass on a dry matter basis was 12 702 and 1814 kg/ha, respectively. Leaf biomass excluded litter fall, which was substantial over the dry season.

Effects of undersowing

Use of fertilizer and type of practice significantly affected maize yields. Undersowing gave the best yields both with and without fertilizer. In the absence of fertilizer, undersowing increased yields by 50 and 98% over sole maize under conventional and reduced tillage, respectively. The relative difference was less dramatic with fertilizer, but undersowing yields were still 600 and 1000 kg higher than conventional and reduced tillage, respectively. From an agronomic perspective, these results clearly demonstrate that undersowing with *Tephrosia* is a beneficial practice under smallholder conditions with and without fertilizer.

Table 1. Maize yields (kg/ha), Trial 1: agroforestry-reduced tillage trials/demonstrations, 1998/99

Treatment effects	Continuous maize, conventional tillage	Continuous maize, reduced tillage	Undersowing *Tephrosia* with 2nd season fallow	Means	Probability >*F*
Type of practice	2770	2478	3376	2875	0.0315
Fertilizer					<0.0001
with	1146	871	1720	1244	
without	3922	3502	4536	3970	

Effects of reduced tillage and retention of crop residues

Contrary to expected results, maize yields were depressed under reduced tillage relative to conventional ridging. The retention of crop residues on the surface to improve soil physical and biological properties appeared to have little effect because of the limited quantity of residues available and their disappearance from termite activity early in the season. This meant little surface protection and return of organic matter to the topsoil. These results suggest that the compacted, degraded and low organic matter state of smallholder soils limits the root growth of crops under conditions of minimal tillage. The implication is that this system of reduced tillage needs a more fertile base with excellent farm management, a situation requiring a longer timeframe for the required changes in soil conditions. One could argue that this was achieved to some degree with undersowing from the large addition of quality biomass to the soil, which also offered simultaneous protection of the soil surface as it was not consumed by termites. However, without a control of undersowing using conventional tillage, the magnitude of this effect remains unknown.

Trial 2: Dedza Hills annual undersowing

Table 2 shows the second season maize yields from this trial. The average stem and leaf biomass on a dry matter basis was calculated as 2329 and 588 kg/ha, respectively. Leaf biomass excluded litter fall which was substantial over the dry season.

The results demonstrate a significant yield response by undersowing with and without fertilizer. In the latter scenario, undersowing increased yields by over 49% relative to sole maize with no fertilizer. It also yielded only 17% less than sole maize with the full rate of nitrogen fertilizer. Half the rate of nitrogen fertilizer increased maize yields from undersowing by 31%. This was a 10% increase over the sole maize with the full rate of nitrogen fertilizer, but at considerably lower cost. Although this trial was managed by extension staff in a site with a fertility base higher than average smallholder soils, the results probably reflect the achievement of an above-average farmer.

Table 2. Maize yields (kg/ha), Trial 2: Dedza Hills, 1998/99

Treatment effects	Means
Maize, no fertilizer	1665
Maize + 96 kg N/ha	2989
Undersowing, no fertilizer	2486
Undersowing + 48 kg N/ha	3266
Overall mean	2601
Probability >*F*	<0.0001
SE	40

FINANCIAL ANALYSIS: METHODOLOGY

Nair (1990) argues that financial considerations are the prime factors that determine the advantage of agroforestry to the farmer. This sentiment is also expressed by Hosier (1989) who argues that "for smallholders throughout the developing world to adopt agroforestry techniques, they must be convinced that the benefits of such innovations exceed the costs. Thus for agroforestry to successfully spread, it must be economically profitable to the smallholders who are practising it".

Therefore, having examined the agronomic aspects of the trials above, it is necessary to extend these to financial interactions. This requires an evaluation and comparison of all the financial costs and benefits of the practices on trial. For the agroforestry practices, costs are made up primarily of labour for such operations as planting and cutting down, with benefits derived from agronomic net benefits in the form of incremental maize yields, and tree by-products. In contrast to annual cropping enterprises, the costs and benefits of undersown fallows are spread over time. This complicates the financial analysis and is addressed through long-term investment analysis techniques which account for the ebb and flow of costs and benefits over time.

Gross margin analysis

Gross margin analysis (GMA) is a commonly used farm planning technique and involves comparison of gross margins per hectare (or per head for livestock) for different enterprises (Barnard and Nix, 1993). The gross margin of an enterprise is "its enterprise output less the variable costs attributable to it" (Barnard and Nix, 1993). Variable costs are defined as those that are specific to the enterprise and vary in direct proportion to the size of the enterprise, e.g. fertilizer and seed in the case of arable crops. The output is determined by multiplying the enterprise yield by the price of the product.

The advantage of GMA is that, although based on budgeting procedures, it is more computationally efficient as it does not require full cost accounting (Barnard and Nix, 1993). The major disadvantages are that, as for budgeting, it is not an optimizing technique, and in addition it ignores fixed costs (Scherr *et al.*, 1992). The latter criticism is not serious in the Malawian context as the smallholder cropping system has a limited fixed-cost element in the form of fixed structures or machinery. Therefore GMA is selected as the method for short-term financial evaluation for reasons of computational efficiency.

This method is acceptable when comparing two annual enterprises, but a problem arises with regard to comparisons between annual enterprises and those with a gestation period longer than a year, such as undersown fallows. The issue here is at which point in the cycle to compare gross margins. At the start, the long-term enterprise is discriminated against as benefits of the technology are yet to appear. At maturity the long-term enterprise is favoured as full benefits are apparent whilst establishment costs are ignored.

For maize-based agroforestry practices, the second option is a useful exercise in order to get a perspective on the comparative gross margins that the farmer can expect once the agroforestry practice has matured. The long-term financial viability of the practice, including establishment costs, is addressed in the following section using time-discounted cost–benefit analysis (CBA).

Cost–benefit analysis

A number of methods of assessing the value of longer-term enterprises have been developed, their common theme being a valuation of the incremental costs and benefits associated with the enterprise discounted over time. Although it is valid to compare the stream of benefits and costs over time of a particular enterprise without discounting, this assumes that the farmer is indifferent between current and future consumption. Nevertheless, discounting is one of the most controversial features of CBA (Scherr *et al.*, 1992), largely due to uncertainty over selecting the discount rate.

The most commonly used rate is the ruling bank saving or lending rate (Gittinger, 1989; Christopherson, 1991), although it has been suggested that these rates discriminate against longer-term enterprises such as agroforestry (Pearce and Turner, 1990). The solution to this is the use of the 'social time preference rate' (Gittinger, 1989; Christopherson, 1991; Williams, 1992) which should be lower, reflecting the longer time horizon for society than for the individual (Gittinger, 1989). On the other hand, Hosier (1989) and Williams (1992) argue that peasant farmers prefer current consumption and as such have a high discount rate.

The bottom line is that there is no general agreement on the criteria for determining the choice of discount rate (Abalu, 1975). Abalu, evaluating perennial crop production in Cameroon, opted to use the ruling government's borrowing rate as the discount rate. This convention is followed here, as the focus is on the financial costs and benefits to the farmer, as opposed to the nation.

Benefit–cost (B/C) ratio

The B/C ratio is calculated by dividing the present value of the benefit stream by the present value of the cost stream as follows:

$$\frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

The formal selection criterion for this measure is to accept all investments with B/C ratio greater than or equal to 1 when the cost and benefit streams are discounted at the opportunity cost of capital. Gittinger (1989) argues that ranking projects on this basis is not recommended, as projects with high costs and benefits are discriminated against.

The major disadvantages of the B/C ratio are that the result is dependent on where netting-out occurs in the stream of costs and benefits (Gittinger, 1989; Williams, 1992), and a discount rate needs to be selected. One advantage is that it is a useful measure for establishing by what percentage costs would have to increase (or benefits fall) to make a project financially unattractive (Gittinger, 1989). As such, the B/C ratio is selected as the measure of investment appraisal in this paper, as it provides a useful yardstick for comparison between alternative farm enterprises.

FINANCIAL ANALYSIS: RESULTS

This section undertakes a financial analysis, both short- and long-term, comparing the agroforestry practices with a number of annual non-agroforestry maize production options. (The Dedza trial is subjected only to GMA as all the options are annual.) Firstly, the full range of maize production practices that are evaluated are listed. Secondly, the GMA and CBA results are presented, discussed and conclusions drawn.

Trial 1: agroforestry-reduced tillage trial/demonstrations

The following six trial plots were analysed:

- maize conventional tillage — CT 0N
- maize +N conventional tillage — CT +N
- maize reduced tillage — RT 0N
- maize +N reduced tillage — RT +N
- maize Tv reduced tillage — Tv 0N
- maize Tv +N reduced tillage — Tv +N

Gross margin analysis results

The GMA results for the reduced tillage trial results are presented in Figure 1, in descending order. The gross margins for all options are calculated for year 3. The fertilized undersowing with *Tephrosia* option returns the highest hectare gross margin (MK14 508) followed by conventional tillage fertilized maize (MK9601) and reduced tillage fertilized maize (MK9141). All of the unfertilized options return significantly lower gross margins, with both the conventional and reduced tillage unfertilized alternatives showing negative gross margins.

These results suggest that:

- with fertilizer, application to maize undersown with *Tephrosia* is the best option
- without *Tephrosia*, conventional tillage makes more financial sense than reduced tillage both with and without fertilizer
- without fertilizer, undersowing *Tephrosia* is a better option than not undersowing, irrespective of the tillage regime

Cost–benefit analysis results

The CBA results, discounted over a 20-year time horizon with conventional tillage with no fertilizer as the base case, are illustrated in descending order in Figure 2. At a discount rate of 50%, in line with commercial bank lending rates and the MRFC credit rate, the three fertilized options return B/C ratios greater than one, with the fertilized *Tephrosia* option showing an excellent result. Reduced tillage with no fertilizer is not a recommended investment option as the labour cost savings are less than the fall in maize income due to the lower yield generated. The unfertilized *Tephrosia* option is also not financially attractive in the long term as the incremental yield does not match the extra labour costs and loss of harvest in the fallow year, unless that land is not targeted for production in that year.

The following conclusions can be drawn from the above GMA and CBA:

- maize production under the reduced tillage system is not recommended as an alternative to conventional tillage as lower yields are not matched by reduced labour requirements

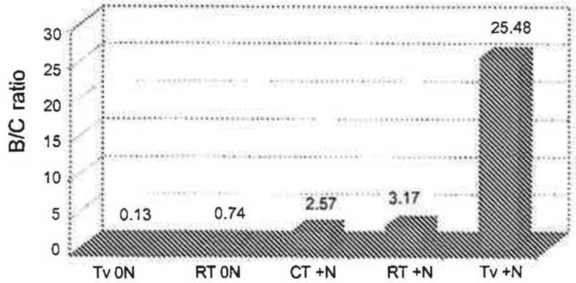

Figure 2. Benefit–cost ratios (at 50%), Trial 1: agroforestry-reduced tillage trials/demonstrations.

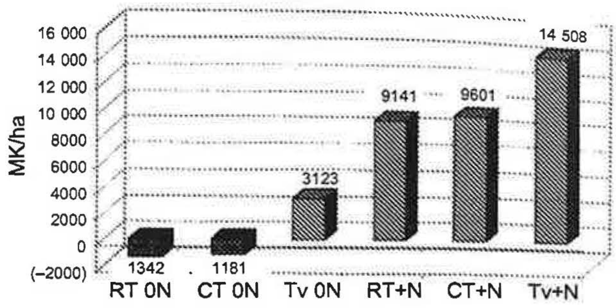

Figure 1. Hectare gross margins (MK/ha), Trial 1: agroforestry-reduced tillage trials/demonstrations, 1998/99.

- undersowing with a second season fallow is recommended only if fertilizer is applied.

Trial 2: Dedza Hills annual undersowing

The following four trial plots were analysed (note that undersowing + fallow was excluded as it was in its fallow season):

• maize conventional tillage	Mz 0N
• maize *Tephrosia*	Tv 0N
• maize *Tephrosia* +N	Tv +N
• maize +N conventional tillage	Mz +N

Gross margin analysis results

The GMA results for the Dedza annual undersowing trial results are presented in Figure 3 in descending order. The gross margins for all options are calculated for year 2. The following conclusions can be drawn from the GMA results above:

- it makes better financial sense to produce hybrid maize with a combination of organic and inorganic fertilizer rather than using one nutrient source in isolation
- when used in isolation, organic fertilizer in the form of *Tephrosia* provides a better financial return than inorganic fertilizer.

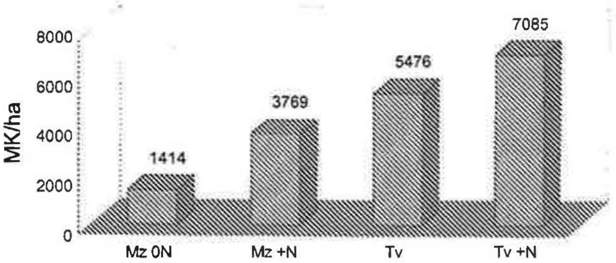

Figure 3. Hectare gross margins (MK/ha), Trial 2: Dedza Hills, 1998/99.

CONCLUSIONS

Undersowing *T. vogelii* with maize is clearly a highly beneficial practice for smallholder farmers in Malawi, generating high yield and economic returns for reasonable levels of labour. The results show that a modest addition of nitrogen fertilizer will provide a more substantial and secure return to the average farmer if resources permit the purchase of fertilizer. To provide a more comprehensive understanding of undersowing with *Tephrosia,* further research is recommended to investigate long-term effects on crop yields and on the physical, chemical and biological properties of soils. The system of reduced tillage presented here suggests that conventional ridging should be continued, as long as it is done on contour, otherwise water run-off and loss of valuable topsoil will increase, leading ultimately to sheet and gully erosion with consequent reductions in farm productivity.

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DISCUSSION

W. Sakala. What is the minimum amount of nitrogen to be added to *Tephrosia* for the farmer to gain better yields?

I. M. H. I have no information on this. MAFE used rates of about 46–48 kg N for the trial results presented.

A. M. Chirembo. Tephrosia alone does not seem to be a viable technology, but *Tephrosia* + 46 kg N gives a very good yield. Did you compare *Tephrosia* + 46 kg N with 46 kg N alone?

I. M. H. Tephrosia alone (or with fertilizer) is a viable technology, both agronomically and financially if undersowing on an annual basis, i.e. no *Tephrosia* fallow year. We did not compare *Tephrosia* + 46 kg N to maize + 46 kg N, only maize + 96 kg N. However, *Tephrosia* + 46 kg N outperformed maize + 96 kg N.

Markets and livelihoods: lessons from farming systems research in Blantyre/Shire Highlands

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ABSTRACT

The fundamental lesson from farming systems research in Blantyre/Shire Highlands is that, in the absence of affordable seed-fertilizer technology, smallholders are responding to maize deficits with market strategies to improve income security. Smallholders generate income by selling food crops, selling labour, and by off-farm enterprises. Market strategies are most important for poorer households with the largest maize deficits. This integration between markets and livelihoods has important implications for agricultural research and poverty alleviation. New technology must be seen from the viewpoint of market demand rather than from the narrower perspective of crop management. We illustrate how the markets for pigeonpea, beans and sweet potato can be used to provide economic incentives for the adoption of IPM strategies. For poverty alleviation programmes, greater emphasis is required on linking smallholders with markets. The definition of household food security must be broadened to include income security. Creating market opportunities for smallholders will require strengthening weak links in the production–distribution–marketing web for food crops, and building partnerships between smallholders and the private sector.

INTRODUCTION

Markets lie at the heart of the new strategy for agricultural development in Malawi. The marketing of smallholder crops (with the exception of cotton and tobacco) was liberalized in 1987. In 1990 the Special Crops Act was amended to allow smallholders to grow burley tobacco for the first time. In 1994 the Agricultural Produce (Marketing) Regulation Act was revoked and the ban on private exports of agricultural produce was lifted. In 1995, pricing for smallholder crops was liberalized. On the input side, the marketing of fertilizer and hybrid seed was liberalized in 1993, while price subsidies for fertilizer and hybrid seed were abolished in 1994. With the exception of maize, for which there is a price band and the export of which is still restricted, smallholders in Malawi now operate within a free market economy.

At the micro-level, we still have much to learn about the role of markets in rural livelihoods.

We offer three propositions:

- smallholder livelihoods are more closely integrated with markets than we think;
- IPM strategies to improve smallholder livelihoods must be market-driven;
- market behaviour illustrates the resourcefulness of the resource-poor.

The UK Department for International Development's country strategy for Malawi takes an ambivalent view of markets (DFID, 1998). Market liberalization is acknowledged to be "a good thing", but only in the long run. In the short run, product and factor markets are "shallow", "lack competition", and "fail" poorer smallholders. Consequently, DFID's approach to poverty alleviation has consisted largely of welfare interventions in order to protect smallholders from market failure.

We argue that markets should be seen as an opportunity and not as a threat. A more appropriate focus for poverty alleviation in the Blantyre/Shire Highlands would be linking smallholders with markets: identifying market opportunities, facilitating market access, and creating partnerships between farmers and the private sector to allow Malawi to compete effectively in regional and world markets. A strategy, in other words, that treats poor smallholders not just as short-term beneficiaries but as long-term business partners.

THEORETICAL ASPECTS

Economists normally test hypotheses with the help of a formal economic model. The approach of this paper, however, is inductive and builds on insights gleaned from field research. We begin by outlining some key concepts.

Livelihoods

A livelihood has been defined as "the capabilities, assets (including both material and social resources) and activities required for a means of living" (Scoones, 1998). Implicit in this concept is the recognition that the sources of household income are diverse and include off-farm enterprises as well as farm production.

Smallholder households

It is impossible to define a smallholder household without reference to markets. A recent textbook states: "Peasants are households which derive their livelihoods mainly from agriculture, utilize mainly family labour in farm production, and *are characterized by partial engagement in input and output markets which are often imperfect and incomplete"* (Ellis, 1993; emphasis added). Thus smallholders are farmers with one foot in the market and the other in the subsistence economy.

The market

Originally, a 'market' meant a physical location where buyers and sellers came together in order to exchange products and services. In economics, however, the term market is used to refer variously to any network of dealings between buyers and sellers of a particular product, to products that are regarded as close substitutes, or to aggregate demand for a particular product. Economists divide markets into two types:

- product markets – the market for different types of crops, and for income-generating activities (re-sale of farm produce, crafts, and services);
- factor markets – the market for inputs into farm production (land, labour, fertilizer).

Why do smallholders enter the market?

Economic theory allows us to predict the circumstances under which households will enter the product and factor markets (Ellis, 1993).

- Households will sell more farm products (including food crops) and purchase more market goods (including food and fertilizer) when there is a rise in the value of farm products relative to those of market products.
- Households will grow more cash crops when the marginal revenue product from these crops exceeds the marginal revenue product from competing food crops.
- Households will allocate more labour to off-farm enterprises when the marginal product of labour in these activities (earnings, or the market wage) is higher than the marginal product of labour in farm production.

Markets and new technology

Farmers will adopt new technology only if it significantly lowers their production costs. The objective of agricultural research, therefore, is to develop technology that lowers the unit cost of production. If new technology is for staple crops or subsistence commodities for which demand tends to be inelastic (relatively unresponsive to changes in price), the price of that commodity will tend to decline as output increases relative to demand. If, however, new technology is for the production of commodities that can be traded (exportable goods and those that compete with imports), there is less of a tendency for the price of the commodity to decline. Producers keep a larger share of the benefits while consumers receive less.

Resourcefulness

Smallholders continually re-allocate resources in response to changes in economic conditions. The ability to perceive these changes and to allocate resources accordingly is an important skill, particularly when change is rapid. In economics, this skill is defined as "the ability to deal with disequilibria" (Schultz, 1975). We shall use the term 'resourcefulness'. Resourcefulness is a component of livelihoods, which includes the capabilities that households bring to optimizing their own particular combination of material and social resources.

THE DATA

The data derive from research reports by the FSIPM socio-economic team over the three crop seasons 1996–99, and include the following.

- A baseline survey, administered in 1996/97 to provide information on farm size, crops, fertilizer use, and farmers' experience with the IPM strategies (Orr *et al.*, 1997). Using a structured questionnaire, we surveyed a sample of 120 households (60 households that participated in on-farm trials and 60 that did not). Further data were obtained from the same households in panel surveys conducted in 1997/98 and 1998/99.
- Special-purpose surveys on specific aspects of the farming system. These included a survey of 30 *dimba* growers in Matapwata EPA in 1998/99 (Orr *et al.*, 1999a) and a survey of 60 sweet potato growers in 1998/99 (Mwale *et al.*, 1999c).
- Case studies of households to provide detailed information on particular topics such as pest management strategies for individual crops (Orr *et al.*, 1999b; Mwale *et al.*, 1999a) or off-farm income (Orr *et al.*, 1999c).
- Interviews with key actors in the market for pigeonpea, including producers, traders, intermediate traders, and members of the Grain and Legume Development Association Ltd.

THE ALL-PERVASIVE MARKET

Product markets: farm income

Markets are often associated with purely commercial enterprises. In Blantyre/Shire Highlands three such enterprises stand out.

- Burley – roughly 3000 smallholders grow burley tobacco, which is traded on the world market through the auction floor at Limbe. Ten per cent of the households sampled in the baseline survey grew burley.
- *Dimba* vegetables: 13% of the households sampled in the baseline survey grew high-value vegetables such as

cabbage and tomato (Orr *et al.*, 1997). Vegetable production was concentrated in Matapwata EPA.

- Milk – unprocessed milk is traded through the Shire Highlands Milk Producers Association, a farmers' organization with 2100 members owning 3900 cross-bred Holsteins. Average daily production is 9500 l (B. Lewis, personal communication, 1999). Only three households in our baseline survey owned dairy cows, however.

Tradeables such as burley or milk are only the tip of the iceberg. A feature of the farming system in Blantyre/Shire Highlands is that there is no clear distinction between 'food' and 'cash' crops (Orr *et al.*, 1997). Table 1 shows that, of 22 important crops, all except burley were grown both for sale and consumption. Fifteen of these crops were normally sold by half or more of the households that grew them. Among the eight crops that were grown by over half the sample, the three most widely grown cash crops were velvet bean, pigeonpea and field pea. Ranking crops by their importance as a cash crop, the highest scores were recorded for three food crops: field pea, beans and pigeonpea.

Field pea (*Pisum sativum*), an orphan crop excluded from national crop statistics, is the most popular cash crop at our research sites. On *dambo* land in Mombezi EPA, a first crop is intercropped with sweet potato and planted in November; a second crop is planted in March as a relay crop with maize; and a third crop is intercropped with sweet potato that is planted in June. In 1998/99, prices for the first and third crops averaged 25MK/kg.

The market orientation of rural households in Malawi also emerges strongly from nationwide survey data (Longley *et al.*, 1999). One-third of households cultivating 0.5 ha or less stated that their primary source of income was crop sales. The most important cash crops for these households were sweet potato (31%), maize and vegetables (24%), groundnut (22%), and pigeonpea and cassava (20%). The share of income from sweet potato, cassava and pigeonpea was highest among households with the smallest holdings.

Food security versus income security

Why do smallholders, most of whom have a food deficit, sell food crops? Economic theory suggests that both types of household will sell rather than consume food crops when the value of crop sales exceeds the value of food purchases. Peters (1993) has noted the way that households in southern Malawi generate income by 'playing the markets', selling one food crop to buy and trade in another.

Marketing of food crops also reflects the low economic returns from maize production. Table 2 shows that, on a full-cost basis, the benefit–cost ratio (BCR) for fertilized, composite maize was 1.8. A BCR of 2 is normally regarded the minimum requirement for farmer adoption of new technology. Valuing all inputs on a cash basis, returns over variable costs (RAVC) for composite maize averaged 5150MK/ha. This was higher than the RAVCs for beans and pigeonpea, but four times below the RAVCs for sweet potato and field pea. On a cash-cost basis, the BCRs for sweet potato, pigeonpea and beans were all higher than for composite maize.

In Blantyre/Shire Highlands, therefore, the new seed fertilizer is profitable only when grown for household consumption. This also holds for Malawi in general (MoAI, 1999). It remains cheaper for maize-deficit smallholders to grow maize than to buy it. It is even cheaper, however, for smallholders to grow other food crops and use the proceeds to

Table 1. Integration in product markets, FSIPM sites, Blantyre/Shire Highlands RDP

Crop	Farmers growing (%)	Farmers selling (%)	Share sold (%)[a]	Cash crop score[b]
Burley	9	100	100	10.8
Cabbage	11	62	91	6.7
Chillies	15	56	90	1.8
Millet	23	33	75	1.8
Soyabean	23	71	52	0
Cowpea	29	26	36	0.8
Tomato	31	67	83	8.3
Cassava	37	48	66	3.5
Groundnut	39	51	48	4.3
Velvet bean	43	65	62	3.5
Hybrid maize	63	51	46	15.5
Sorghum	68	18	52	0.8
Field pea	76	68	65	42.7
Sweet potato	78	56	63	16.0
Local maize	79	25	34	11.7
Pigeonpea	91	67	53	22.8
Beans	93	57	51	32.2

Source: Orr *et al.* (1997b).
[a]Shares calculated as 25 for ¼ or less, 50 for ¼ to ½, 75 for ½ to ¾, and 100 for all.
[b]Scores calculated as 1.0 for rank 1, 0.5 for rank 2, 0.3 for rank 3.

Table 2. Crop budgets for major food crops at FSIPM sites, Blantyre/Shire Highlands RDP

Variable	Composite maize	Sweet potato	Field pea intercrop	Pigeonpea intercrop	Beans intercrop
Benefits					
Yield (kg/ha)[a]	1841	19381	1601	133	212
Clean yield (kg/ha)[b]	–	11360	–	–	–
Adjusted yield (kg/ha)[c]	1473	9088	1281	106	170
Maize equivalent (kg/ha)	1473	2894	584	95	158
Unit price[d]	8.5	3.0	25	6.5	31
Gross benefits (MK/ha)	12521	27264	32025	689	5270
Variable costs					
Materials (MK/ha)					
Seed[e]	1000	1251	10855	63	540
Fertilizer[f]	1956	–	–	–	–
Credit[g]	584	–		–	–
Labour requirements (man hours/ha)[h]	850	910	160	160	160
Unit price (MK/day)[i]	23	23	23	23	23
Imputed labour cost (MK/ha)	3258	3488	613	613	613
Total costs	6798	4739	11468	676	1153
Net benefits					
Return over variable costs (MK/ha)	5150	22525	20597	13	4105
Benefit–cost ratio (full-cost basis)	1.8	5.8	2.79	1.2	4.6
Benefit–cost ratio (cash-cost basis)	3.5	21.8	2.95	10.9	9.7
Gross returns to labour (MK/day)	88	180	1200	26	197
Returns to labour (kg maize equivalent/day)	10	19	22	4	6

[a]Yields from FSIPM on-farm trials: sweet potato, Mangunda, 1998/99; composite maize (Masika) from on-farm trials in Matapwata and Mombezi EPAs in 1998/99 (n=238); pigeonpea (ICP 9145) from Chiradzulu upland, 1997/98; beans (Kaulesi) average upland in Mombezi and Matapwata, 1997/98. Field pea, crop cuts in Mombezi *dambo*, 1998/99 (three fields).
[b]Sweet potato yields adjusted downwards for damage from sweet potato weevil. Damage is based on researchers' perceptions. Farmers' perceptions give lower damage (i.e. tubers with traces of weevil damage may still be used for sale or home consumption).
[c]Yields adjusted downwards by 20% to allow for treatment and management factors (CIMMYT, 1976).
[d]Local market prices. ADMARC consumer price for maize, February 1998/99. The ADMARC consumer price is used on the assumption that the household is maize-deficit and will buy maize.
[e]Composite seed (Masika) @ 40 MK/kg.
[f]Fertilizer rate @ 50 kg/ha N using 23 : 21 + 4S (ADMARC price MK 895 for one 50 kg bag in 1998/99), plus 10% for transport from depot to field.
[g]36% Malawi Rural Finance Corporation interest rate, payable within 10 months.
[h]Labour requirements from Werner (1987) and Sam (undated) for weeding and harvesting sweet potato.
[i]Wage rate for male estate labour, 1998/99, Mombezi EPA, @ 6 h/day.

buy maize. While the net benefits from 1 ha of composite maize (MK5150) would buy 10 bags of maize, the net benefits from 1 ha of field pea or sweet potato (>MK20 000) would buy almost 50 bags. Maize is grown to provide a certain minimum level of household food security. At the margin, however, it is economically rational for smallholders to accept income security through the sale of cash crops as a substitute for food security.

The rationale behind the sale of food crops is evident in the recent increase in production of sweet potato. A recent survey at our research sites (Mwale *et al*., 1999) obtained the following results.

- Households ate sweet potato as a substitute for *nsima* for 5 months of the year (May–August). This extended the period in which they were self-sufficient in maize.
- The recent increase in production of sweet potato was chiefly for sale, not for home consumption. Revenue from the sale of sweet potato was spent on maize and household necessities such as relish and salt.
- More households in the lowest category of food security used the revenue from sweet potato to buy maize.

Table 3. Resources and market strategies for fertilizer users and non-users, FSIPM sites, Blantyre/Shire Highlands RDP

Variable	Users (n=64, 1996/97)	Non-users (n=56, 1996/97)	Significance level[a]
Socio-economic			
Female-headed households (%)	44	57	NS
Resources			
Total maize area (ha)	0.67	0.63	NS
Hybrid maize area (ha)	0.38	0.28	NS
Total workers (no.)	3.39	2.64	*
Adult males (no.)	1.42	1.02	*
Non-resident workers (no.)	0.46	0.CAPL	*
Goats (no.)	1.04	0.43	*
Food security: (months buying)			
1996/97	8	6	*
Sale of food crops: (% selling)			
Local maize	32	18	NS
Hybrid maize	55	45	NS
Beans	51	65	NS
Pigeonpea	58	78	*
Sweet potato	44	69	*
Groundnuts	42	71	*
Source of cash for fertilizer purchases in 1997/98 (% households reporting)	(*n*=57, 1997/98)	(*n*=48, 1997/98)	
Crops	26		
Livestock	5		
Ganyu	26		
Geni	14		
Transfers	21		
Salary income	9		
Total	100		
Source of income for maize purchases in 1997/98 (% households reporting)	(*n*=57, 1997/98)	(*n*=48, 1997/98)	
Crops	30	23	NS
Livestock	7	4	NS
Ganyu	25	42	*
Geni	21	16	NS
Transfers	18	38	*
Salary income	12	12	NS
Total	100	100	

Sources: FSIPM Baseline Survey, 1996/97, Panel surveys 1997/98, 1998/99.
[a]*,Significant at 10% level or above by chi-square or *t* test.
NS, not significant.

- The BCR (cash-cost basis) for sweet potato was 7.6, compared to 1.1 for fertilized composite maize, making sweet potato an attractive cash crop.

Specialization in food crops other than maize depends on the extent of the market. The market for maize in Blantyre/Shire Highlands is extended by cross-border trade with Mozambique. In 1996/97, a poor harvest in southern Malawi coincided with a bumper harvest in Niassa Province. Thousands of small traders from Malawi descended on the province, offering farmers high prices for their maize. It is estimated that 50 000 mt of maize crossed the border into Malawi (Whiteside, 1998). This trade benefits both maize producers in Mozambique and maize consumers in Malawi.

Product markets: off-farm income

Baseline data showed that off-farm income accounted for 57% of total cash income at our research sites. The share of off-farm income was significantly higher for female-headed households (Orr *et al.*, 1997). A study at our research sites (Orr *et al.*, 1999c) showed the integral role of off-farm enterprises in smallholder livelihoods.

- Off-farm enterprises were not purely seasonal activities concentrated in the hunger period, but encompassed the entire year (Figure 1). Of 22 enterprises studied, 10 (45%) were annual. Specialists in *geni* combined business with farming. Crafts were the most seasonal form of off-farm income as they relied on raw materials that became available only in the dry season.

No.	Category	Enterprise	Marital status	Net income (MK/month)	Returns to labour (MK/day)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	*Geni*	Brewing *kachasu*	FHH	1324	40												
2		Selling goat hides	MHH	2435	78												
3		Selling *kanyenya*	MHH	1052	44												
4		Trading ADMARC maize	FHH	57	31												
5		Trading flour (*ufa*)	MHH	350–531	48–163												
6		Selling *zophikaphika*	FHH	469	50												
7		Selling snuff	FHH	97	36												
8		Trading *madeya*	FHH	416–904	28–52												
9		Tailoring	MHH	2203	37												
10	*Okala*	Village shop-keeping	MHH	1625	26												
11	*Ganyu*	Village carpentry	MHH	647–1152	61–68												
12		Building houses	MHH	1166	50												
13		*Ganyu*: land preparation		676	25–40												
14		*Ganyu*: weeding		312	26												
15		Permanent *ganyu*	FHH	1024	28												
16		Estate *ganyu*	MHH	526	22												
17		Selling firewood	MHH	262	14												
18	*Thandize*	Moulding bricks		–	29												
19		Selling thatching grass	MHH	469	50												
20	Crafts	Making baskets	MHH	1003	25												
21		Making mats	MHH	137	7												
22		Making *nkhokwe*	MHH	195	30												
23		Making hoe and axe handles	MHH	18	9												
24	Profession	Herbal medicine	FHH	667	208												

= Hunger months (*nthawi ya njala*)   = Months of off-farm enterprise

Figure 1. Off-farm enterprises, FSIPM sites, Blantyre/Shire Highlands RDP.

- Returns to labour for *geni* (median, 48MK/day) were higher than for seasonal *ganyu* (weeding, 26MK/day). Only for crafts were average returns lower than for *ganyu* (median, 17MK/day). Crafts were popular with elderly men who had few alternative ways of earning cash income.
- Off-farm enterprises were not short-term coping mechanisms, but strategies that required foresight, planning and business acumen. Shop-keeping was used to generate working capital for *dimba* cultivation. Revenue from trading *madeya* and selling goat hides was used to buy fertilizer. Earnings from bricklaying were invested in secondary education.
- The high share of off-farm income among female-headed households found in the baseline survey is explained by the facts that most specialists in *geni* are women, and that most *geni* enterprises extend throughout the year.

Factor markets: fertilizer

Smallholder integration in the market for fertilizer has been a concern since the credit collapse in 1993/94. In 1993/94, 64% of the households at our survey sites used fertilizer; in 1996/97, the year of the baseline survey, only 53% of households in the sample applied fertilizer and 45% of the area planted to maize was unfertilized (Orr *et al.*, 1997).

Table 3 compares resources and market strategies between fertilizer users and non-users at FSIPM research sites. Both groups had the same area planted to maize. However, non-users had significantly fewer labour resources, including fewer adult males. They also had less liquidity, with fewer goats to sell and fewer non-resident workers who might serve as a source of cash. As a direct consequence of their inability to use fertilizer these households had lower food security, with a maize deficit of 6 months in 1996/97. To overcome this deficit, non-users relied heavily on market strategies. A significantly higher share of non-users sold food crops such as pigeonpea, groundnut and sweet potato. And a significantly higher share of non-users bought maize with cash earned from *ganyu* and from income transfers from relatives and friends. Among fertilizer users, crop sales and *ganyu* were the strategies most widely used to generate income to buy fertilizer.

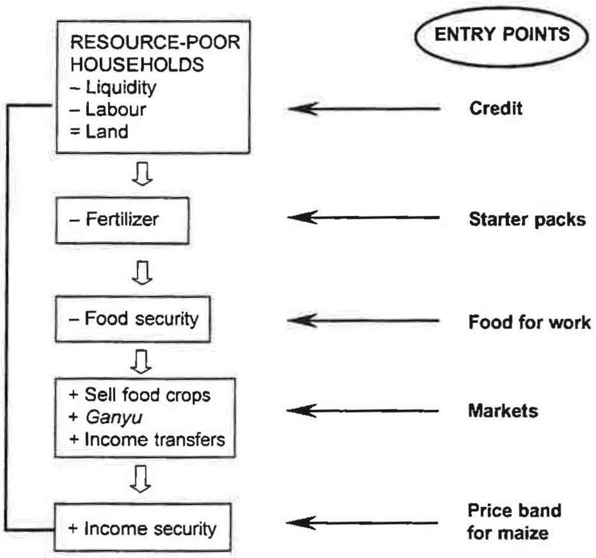

Figure 2. Dynamics of smallholder integration in product and factor markets, Blantyre/Shire Highlands RDP.

Figure 2 illustrates the dynamics of this process. Households may become stuck in a vicious circle if markets cannot provide them with sufficient liquidity both to meet their maize deficit and to buy fertilizer for the following year. To break this vicious circle, there are various policy options. In 1998/99, for example, each household received a starter pack containing enough fertilizer for 0.1 ha. For 24 sample households in our panel survey, this was their only source of fertilizer. For households farming 0.5 ha or less, it is estimated that the starter pack cut the maize deficit by 3 weeks (Longley *et al.*, 1999). Although small, this almost halved the difference in food security between fertilizer users and non-users in 1996/97.

MARKETS AND NEW TECHNOLOGY

Pests

The adoption of IPM strategies in the Shire Highlands is likely to be market-driven. This is not just because smallholders in this peri-urban environment are strongly oriented towards the market, but because it is the market that gives farmers the economic incentive to reduce crop losses from pests. Take *dimba* vegetables, for example. *Dimba* horticulture is a commercial enterprise that offers relatively high returns. To protect these returns, growers buy pesticides. Expenditure on pesticides averaged MK425 (US$10) per household in 1997/98 (Orr *et al.*, 1999a). Most pesticides were applied at levels far exceeding the recommended rates. An IPM approach that reduced pesticide use for *dimba* crops while maintaining yields would immediately be attractive to farmers because it would lower the unit cost of production.

Experience with food crops in Asia (rice) and Latin America (maize) suggests that IPM has been most successful where it replaced high levels of pesticide use and offered substantial savings in cash costs (Orr, 1997). In Indonesia, IPM reduced pesticide applications on rice from an average of four per season in 1986 to 0.8 for IPM-trained farmers in 1991. In Nicaragua, farmers averaged seven pesticide applications on maize before adoption of IPM reduced this to 1.5.

Identifying economic incentives for the adoption of IPM strategies for food crops in Malawi is more difficult since, as a rule, these crops are grown without cash investment in chemical forms of plant protection. Consequently, the adoption of IPM strategies for maize, beans, pigeonpea or sweet potato will not reduce farmers' cash costs. This does not render IPM a lost cause, however. IPM strategies such as varietal resistance or biological control require little or no investment from farmers because the costs are borne by the publicly funded research system. They may also be implemented without expensive training programmes for farmers.

Opportunities for IPM are also created by the frequency with which food crops are marketed. Take beans, for example. In Blantyre/Shire Highlands, both the main crop and, to a lesser extent, the relay crop are attacked by a complex of pests and diseases. Faced with such an array of pests, the task of breeding resistant varieties is daunting. However, the market has created an opportunity for IPM. Early maturing bean varieties earn a price premium because they provide a source of protein during a period of severe food shortage. By a happy coincidence, early maturity may also reduce their exposure to pests and diseases. Thus promoting the spread of quick-maturing varieties may well prove to be the most effective IPM strategy for beans (Orr *et al.*, 1999b).

Markets may also prove critical for the adoption of IPM strategies that involve cultural practices. Sealing cracks on sweet potato ridges within 6 weeks of planting is known to reduce damage from the sweet potato weevil. In Blantyre/Shire Highlands, farmers who grow sweet potato as a food crop weed once, whereas those who grow it as a cash crop weed twice (Mwale *et al.*, 1999a). An IPM strategy that requires additional labour is more likely to win acceptance from market-oriented growers who have already demonstrated their willingness to invest labour in protecting the crop. Markets may also provide a disincentive for the adoption of this IPM strategy, however. Farmers in the Mombezi *dambo* intercrop sweet potato with field pea, a valuable cash crop. The cost of damage to field pea from crack sealing is likely to outweigh the benefits from reduced weevil damage to sweet potato.

Therefore, linking pest management and markets may form the basis of a new approach to IPM for resource-poor farmers, particularly for food crops for which they do not apply pesticides. Essentially, this approach involves three steps.

- Identify the production practices that produce a competitive advantage on local markets. These might include a particular variety, earlier planting, a crop combination, or some other innovation.
- Isolate the varietal traits or techniques that create this competitive advantage.
- Combine IPM strategies with these traits or techniques to facilitate farmer adoption.

The enterprise web: the case of pigeonpea

Attempts to create market opportunities for smallholders frequently fail because they overlook the fact that all products are part of a production–marketing–distribution web (Drucker, 1985). Pigeonpea in Blantyre/Shire Highlands provides an interesting example (Figure 3).

- *Production*: the crop is well adapted to the farming system in Blantyre/Shire Highlands and is widely grown (12 000 ha) as an intercrop with maize. Production in Malawi in 1998/99 was estimated at 91 000 mt.
- *Sales*: pigeonpea is widely sold. Households at our research sites ranked it as their third most important cash crop.

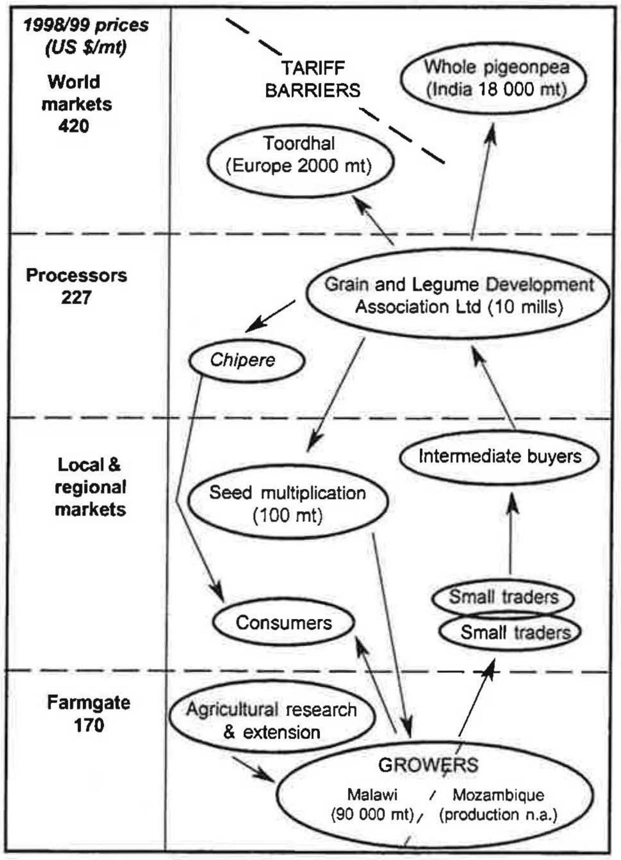

Figure 3. Enterprise web for pigeonpea in Malawi.

- *Processing*: Malawi has the biggest processing industry in the region, with 10 mills. The industry suffers from overcapacity. Recently, a Grain and Legume Development Association has been formed to 'stabilize' prices.
- *Market infrastructure*: the marketing chain is efficient, consisting of numerous small traders who cover a wide market radius. Farmgate prices in 1998/99 ranged from 6 to 9MK/kg. Prices paid by processors started at 8MK/kg in August and peaked at 12.50MK/kg in late October, the deadline for export to India. Buying at 8MK/kg, selling at 12.50MK/kg and deducting the cost of transport and the cost of bags (80 t/kg) gives a profit margin for small traders of 46%. Some analysts regard high marketing margins as a weak link in the enterprise web for grain legumes (MoAI, 1998). Margins for pigeonpea were high in 1997/98, when low supply drove the prices paid to small traders up 17.5MK/kg. The solution, however, is not to control prices but to increase competition among buyers.
- *Prices*: the 'average' farmgate price in 1998/99 was 7.5MK/kg (170US$/t), and the average price paid to small traders was 10MK/kg (227US$/t). Millers' costs were estimated at 107US$/t (administration 2US$/t, bags 5US$/t, freight 100US$/t), giving a cost price of 334US$/t. The minimum trading margin is 20% after interest. This gives an export price of roughly 420US$/t.

Box 1. 'Resourcefulness' – how smallholders adapt to markets

1. Markets as a threat...

Bambo B. (42), his wife, and five children live in Kambuwa village, Matapwata EPA. They cultivate three dryland and two *dimba* gardens. Formerly, the household belonged to a smallholder credit club. With the fertilizer from the credit club the household was self-sufficient in maize and even produced a surplus. But the collapse of seasonal credit in 1994 and subsequent hikes in the fertilizer price have dramatically reduced household food security. The household now runs out of maize in November, 5 months before the next harvest.

Market liberalization has required major shifts in household resources

Geni. In 1994/95 Bambo B. tried to earn cash from *geni*, trading in fish from Nsanje. The next year he tried buying goats and pigs in Nsanje and selling them in Limbe. Neither scheme was successful and the wife has to support the household by trading in *madeya*.

Land. The household rented out part of the largest upland field for MK450 in 1996/97 and for MK750 in 1998/99. The smaller *dimba* garden has been rented out for MK350 in the 1999/2000 season.

Crops. Household energies now focus on *dimba* production. The largest *dimba* field grows one crop of rape and cabbage and two crops each of tomato, mustard and *dimba* maize. The planting of tomato and cabbage is timed to allow harvesting when the household has run out of maize.

Labour. Dimba activities run for a period of 10 months between April and January. Labour demand peaks in the dry months of September and October when the husband spends most of his time irrigating the cabbage and tomato crops. Usually he works alone in the *dimba* while his wife works in the dryland fields. He usually assists her with land preparation and weeding.

Capital. Cabbage and tomato crops require heavy cash investment. By carefully planning which crops to grow and when, the household is able to generate enough cash from *dimba* sales to buy sufficient fertilizer and pesticides. For example, sale of mustard seed provided cash for cabbage seed.

Income from *dimba* crops is highest between December and January. Part of the income is also used to buy maize during the months of food shortage. It also buys fertilizer for the upland fields and labour to help the wife finish land preparation and weeding in time.

In 1998/99, the household obtained APIP fertilizer credit worth MK1675 and harvested enough maize to last until early November. They hope to receive another fertilizer loan next year. In the future, they plan to intensify *dimba* production and buy fertilizer with the cash earned from *dimba* crops rather than depend on credit.

2. Markets as an opportunity...

Mai M. (36) lives with her mother and three young children in Lidala village, Mombezi EPA. She and her mother each cultivate one upland and one *dambo* field. Six years ago (1992) the household used no fertilizer and ran out of maize in September. To buy maize, both women took *ganyu* contracts for land preparation, weeding and banking. Income from cash crops like beans and pigeonpea was spent on necessities like soap.

Market liberalization offered the household the opportunity to grow burley tobacco, a lucrative cash crop. Burley required major changes in the allocation of resources:

Labour. The household now works harder than before and there is less time to rest. Both women suffer periodically from body pains. Work schedules have to be carefully planned to accommodate the labour demands for burley and food crops.

Land. Both the *dambo* fields are planted to maize. Because of the need to rotate burley, the household usually rents or borrows an additional upland field in which they plant maize. This is necessary because of the high risk of crop losses from floods in the *dambo*.

Capital. Membership of a burley club entitles the household to fertilizer credit for both tobacco and maize. In a good year, when there is no flooding in the *dambo*, the household is self-sufficient in maize until February and there is no need to do *ganyu*.

Income. Cash from burley is used to buy clothes rather than maize. This year some cash from burley was spent on the initiation ceremony (*chinamwali*) for her oldest son. Mai Mpenda believes that the greatest benefit from burley has been to provide access to fertilizer that has allowed the household to increase maize production.

In 1998/99, the *dambo* flooded and much of the household's maize was lost. Consequently, they expect to run out by the end of November. To buy maize, the household will revert to its former strategy of contract *ganyu*. The household has now lost maize to floods for 2 years out of 3. Despite this, Mai M. is reluctant to replace maize with cash crops like sweet potato or field pea. In years of low rainfall, upland maize fields perform poorly and they depend on their *dambo* fields. Moreover, these cash crops are harvested earlier than maize and she fears that, by the time maize is available, there will be no money left with which to buy it.

- *Markets*: pigeonpea is a tradeable, sold on the world market. Malawi exports about 20 000 mt each year, worth about US$6 million (Patel, 1998). Malawian pigeonpea reaches India before the harvest of the local crop in December. Demand for imports rises if stocks are insufficient or if the market anticipates a poor Indian crop (Jaeger, 1998).

An enterprise web is only as strong as its weakest link. Where markets have been used to create opportunities for the poor, it has always been necessary to strengthen weak links in the enterprise web (Magor, 1996). There are several weak links in the enterprise web for pigeonpea.

- Supply is inadequate to meet export demand. Competition from the processing industry in Mozambique has reduced the supply available to mills in Malawi, pushing up domestic prices. To increase local production, the Grain and Legume Development Association has launched a seed multiplication scheme for which it is seeking support from aid donors.
- Scope for value-added is limited by a 12% import duty on processed pigeonpea (*toordhal*) to India. The loss in value-added is about US$143/t, of which US$43 is the milling margin and U$100 is foreign exchange (Patel, 1998).
- The highest-yielding variety, ICP 9145, was developed for resistance to *Fusarium* wilt, rather than for its taste and processing qualities. It has no price premium, and milling is more difficult than for local varieties. By contrast, farmers and millers have praised ICEAP 00040 and 00040 for their seed size and taste (Mwale *et al.*, 1999b).

This illustrates the need to see pest management in the wider context of the enterprise web, where resistance to pests and diseases is combined with the other qualities that are desirable for processors and consumers.

THE RESOURCEFULNESS OF THE RESOURCE-POOR

Smallholders may be resource-poor, but they are resourceful in making the most of market opportunities. Market opportunities can be shown in the form of a product/market matrix (Ansoff, 1968). Table 4 adapts this matrix to identify recent changes in resource-allocation in Blantyre/Shire Highlands. Eight separate strategic choices are identified. We focus on three.

- Withdrawal – smallholders in Matapwata have virtually withdrawn from the production of relay beans. *Mbwera* beans were common in the early 1990s, but early cessation of rains in 1996/97 and 1997/98 discouraged many farmers from growing this crop. Some have replaced beans with field pea, which performs better under moisture stress on upland fields.
- Consolidation – some smallholders who grow beans as a maize intercrop have deliberately chosen to plant early-maturing varieties. The varieties Kaulesi, Nyadanawo, Mashunga, and Nambewe ripen 3 weeks or more before Chimbamba. Since other forms of relish are scarce at this time, they command a price premium in local markets. Harvest prices of Kaulesi are 40% higher than Chimbamba (Orr *et al.*, 1999b).

Table 4. Alternative strategic directions for smallholders in Blantyre/Shire Highlands

Market/product	Strategic direction	Description	Blantyre/Shire Highlands
Existing market, existing product	'Do nothing'	Business as usual	
	Withdrawal	Complete or partial withdrawal from market	Unfertilized local maize on marginal soils Hybrid maize Fertilizer Beans (disease pressure) Reduce use of hired labour
	Consolidation	Changes in specific ways the household operates, to maintain a competitive edge	Adopt new varieties (higher yielding, better quality, early maturing) Substitute green manure for fertilizer Substitute composite for hybrid maize
	Market penetration	Increasing market share (difficult in static markets)	Possible for industry as a whole (e.g. smallholder burley)
Existing market, new product	Product development	Maintains present market but develop new product (risky, potentially unprofitable)	Substitute field peas for beans Substitute sweet potato for unfertilized local maize Burley tobacco Irish potato
New market, existing product	Market development	Entry into new markets (e.g. exporting).	Outgrower schemes (paprika, chillies) Contract farming for hotels
New market, new product	Related diversification	Market and product still within broad confines of 'agriculture'	Organic agriculture Agro-forestry Fish farming Dairying and livestock
"	Unrelated diversification	Development into markets and products beyond 'agriculture'	Off-farm income (trading, business)

- Market expansion – commercial growers now plant sweet potato in November in order to be first on the market with their crop. The first crop is normally sold directly from the field, loaded onto trucks, and shipped to town. They have also adopted Kenya, a high-yielding, quick-maturing variety.

Case studies also illustrate the resourceful way that smallholders adapt livelihoods to the threats and opportunities presented by changes in markets (Box 1).

CONCLUSIONS

Our findings derive from field research in Blantyre/Shire Highlands RDP and should not be generalized. However, this does not mean that they lack wider relevance. The distinctive features of the farming system in Blantyre/Shire Highlands – small farms, the importance of off-farm income, and the role of income security – hold up a mirror to the future for other smallholders in Malawi.

Although our findings have not been formally tested, they are consistent with an economic model of the farm household in which smallholders allocate resources according to the relative returns from producing for the market and producing for home consumption. In part, the forces driving this behaviour are structural and stem from a combination of small farms and the low average productivity of the traditional maize-based farming system. Market integration is also the result of the removal of input subsidies, which has made the new seed-fertilizer technology too expensive for many smallholders. Until this impasse is resolved, food insecurity will remain a permanent feature of smallholder livelihoods. The way in which smallholders are responding to this challenge is through the market. This is true particularly for households that cannot afford fertilizer and have the largest maize deficits. A higher-than-average share of these households sell food crops and also sell labour to earn cash to buy maize. Market integration among these households is driven by the need for income security. Thus the households with the greatest need of markets are the resource-poor.

If markets matter for the poor, what are the lessons for researchers and aid donors who want to improve smallholder livelihoods?

For researchers, the major lesson is that research must change from being production-led to being customer-led. New production technology cannot be developed in isolation from the market. This means that researchers must pay more attention to the place of technology in the enterprise web.

- For IPM, strategies for food crops must be viewed not from the perspective of reducing crop losses but from the wider perspective of market incentives.

- For soil fertility technologies, the same principle applies. The history of soil conservation in Malawi during the colonial era illustrates the futility of imposing technology on farmers in the absence of economic incentives. The experience of Machakos in Kenya shows that environmental recovery is possible *"provided that market developments make farming profitable"* (Tiffen *et al.*, 1994; our emphasis).

For government and donors, the major lesson is the importance of linking smallholders with markets. This has several aspects.

- Household food security has to be defined more broadly than in terms of maize production. Other food crops, such as sweet potato, are also substitutes for maize. And households that are not self-sufficient in maize may still be food-secure if they are income-secure and can cover their maize deficit with income from market strategies.

- Welfare approaches to increase food security must be complemented by initiatives to promote income security through the market. Some tradeables – burley, milk – may be inappropriate for poorer smallholders. But there are other opportunities in the markets for food crops such as grain legumes, where smallholders are already active. How can these markets be made friendlier for poorer households?

- Creating market opportunities for smallholders will require careful analysis to identify weak links in the enterprise web for smallholder crops. Is it technology? Or production? Or market infrastructure? Or all of these? Attention to the web is necessary to avoid past mistakes with crop diversification where farmers were encouraged to produce crops for which markets did not exist.

- Linking smallholders with markets will require partnerships with the private sector because businessmen know what the market wants. Farmers and businessmen are in the market for the same reason: to make money. How can government and donors foster partnerships between farmers and business based on mutual interest and dependence? In 1991, 16% of Kenya's 2 million smallholders were growing crops under contract and horticulture exports accounted for 20% of agricultural exports (Jaffee, 1994). This is a measure of what can be achieved and of how far there is still to go in Malawi.

In conclusion, it is time to heed the lesson about markets and livelihoods that has been learnt and successfully applied elsewhere:

> "The market, however imperfect and for whatever reason, is the arena of people's natural, daily behaviour. That is to say, it is part of culture, not just as series of technical interactions, adjusting supply to demand via fluctuating prices. The mistake of anti-market dogma, based on the valid assumption that poor people cannot meet their needs in the market-place, was the belief that people could be separated from this culture and operate in an officially managed substitute culture. Thus given the proven inability of the state to operate this substitute culture on behalf of the poor, we had better search for what the market can do for the poor, given appropriate support for them to compete in these markets."
>
> (Wood, 1994).

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DISCUSSION

C. S. M. Chanika. This is an excellent analysis of the situation in Blantyre/Shire Highlands. However, how long will it take to feed back and be utilized within the project's activities?

A. O. The insights from the FSIPM Project in Blantyre/Shire Highlands will be used by follow-on projects, such as work by ICRISAT on pigeonpea, and by other donors who may be interested to see more projects in the southern region.

A. J. Sutherland. How can farmers be cushioned from the vagaries of markets, for example, flooding markets with a product using a new technology which results in a drop in price and farmers dumping their produce?

A. O. One way of cushioning farmers from 'boom-and-bust' production cycles is to ensure that the market radius is big enough to absorb increased production. This is easier for non-perishables. The wider the market, the greater the scope for specialization.

B. Mwale. Negotiated contracts ensure markets. Farmers in Blantyre/Shire Highlands, particularly sweet potato growers, have begun to link with traders from towns on a more trustworthy and permanent basis.

G. K. C. Nyirenda. There is a need for representatives of the private sector to participate in meetings like this one so that they can give their requirements. For example, with regard to cotton variety development, the industry's requirements are given to researchers who then develop varieties with the appropriate characteristics.

J. M. Ritchie. A market orientation can feed back into setting research targets. For instance, the 6% damaged seed level reported by Dr Jones for pigeonpea seed is probably caused by insect damage. We should determine how seriously that wastage is viewed by buyers before we formulate research programmes.

J. Lawson-MacDowall. I very much agree with looking at farmers in the context of their overall livelihood strategies. There may also be implications for the poorest of the poor – a group notoriously hard to reach. Work we are carrying out looking at resource flows within *mbumbas* suggests extremely poor households (often single older women) are getting by through support from their adult children/close relatives who are involved in market activities.

Some opportunities for demand-driven research in Blantyre/Shire Highlands

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ABSTRACT

This paper briefly reviews some specific researchable constraints related to yield improvement in food and cash crops identified during three seasons of working with smallholder farmers in Blantyre/Shire Highlands. To be fundable by donors, any research proposals must avoid repeating earlier work, must be specific and must include an element of economic assessment. Seven areas of work are identified: (i) improving cowpea yields; (ii) meeting farmers' need for early maturing beans; (iii) increasing farmer yields and profitability from sweet potato; (iv) development of field pea as a cash crop; (v) development of management strategies for pigeonpea pod pests; (vi) understanding linkages between soil fertility enhancement technologies and pest management; (vii) management of root-knot nematodes in green manure legumes.

INTRODUCTION

The purpose of this short presentation is to augment the work of the group which considered research needs by highlighting some specific research needs which arise out of the Farming Systems Integrated Pest Management (FSIPM) Project's experience of working with farmers in Blantyre/Shire Highlands over the last three seasons. It is tempting to formulate a researcher's 'wish list' of topics. However, I intend to deal strictly with researchable constraints on yield improvement in important food and cash crops which have direct relevance to the needs of smallholders.

Avoid repetition

There are a number of key principles which must be followed if research is to be commissioned by donors or NGOs acting on behalf of farmers. Firstly, the proposed research must avoid repeating previous work and build clearly on the literature and recent work, such as the FSIPM Project experiences. For example, the importance of termites as pests in southern Malawi was assessed by the Chancellor College/NRI Soil Pests Project. Using overseas expertise (which is no longer readily available due to shrinkage of the UK research base) the Soil Pests Project identified as far as possible the main species involved in crop damage. Reports are available (Black *et al.*, 1995; Logan *et al.*, 1995; Munthali *et al.*, 1996; Nyirenda *et al.*, 1996). There is not likely to be an early pay-off from more termite-related research in Blantyre/Shire Highlands until some new farm-level techniques (e.g. fungal pathogens) become available after validation elsewhere, for example, the current Department for International Development (DFID)-funded research on fungal pathogens in Uganda in conjunction with the Natural Resources Institute (NRI) and the International Centre for Insect Physiology and Ecology (ICIPE).

Be specific

A second principle is to be as specific as possible. General pest/disease surveys were carried out in the past but donors do not generally fund these types of studies now unless there is a close link to user needs and to specific likely outputs. Work on a general area, such as foliar diseases, is unlikely to attract further donor support, whereas a proposal to increase bean yields in Blantyre/Shire Highlands by screening and selecting specific farmers' bean varieties for earliness, yield and resistance to common bacterial blight and other diseases under farmer management may be more attractive.

Economic assessment

It is important to include in any proposal, a realistic assessment of the economic benefit which is to be expected from the new technology.

SOME FARMER-ORIENTED CONSTRAINTS IN BLANTYRE/SHIRE HIGHLANDS

Causes of low yield in cowpea

Assessment of farmer needs

There is a need to obtain the farmer's perception of the value of the crop and its major constraints. The production chain needs to be examined to determine the end-users and to determine the potential for processing and export. Investigations with farmers should follow up the survey by Lawson-McDowall (1997). Nseula types are preferred for intercropping but on-farm yields are poor and need to be objectively quantified and compared with published on-farm yields elsewhere. FSIPM Project surveys highlighted the importance of *Alectra vogelii* on this crop (Ritchie and Koloko, 1998), but discussions with farmers suggest that they are unaware of the parasitic nature and effects of this weed. There is a need to carry out a restricted survey of incidence/severity of *Alectra* and other pests on cowpea in southern Malawi. The published literature can be used to estimate likely yield gains from improved pest management and/or varietal improvement. If necessary, laboratory pot experiments can also provide information on the yield depression resulting from different intensities of parasitism by *Alectra*.

Development of Alectra *resistance in cowpea for Malawi*

- This work could be part of a regional programme with Zimbabwe and Tanzania where cowpea is also an important crop.
- In Malawi both local and elite research varieties of cowpea are highly susceptible to *Alectra* (Mainjeni and Riches, p. 226).
- Resistance is available (variety B359).
- Transfer of resistance genes to local varieties is possible using available International Institute of Tropical Agriculture (IITA) expertise.
- Newly trained staff expertise for resistance screening is available within the Department of Agricultural Research (Mrs C. Mainjeni).
- Quarantine work on exposure to different *Alectra* biotypes can be done in a third country (e.g. facilities are available at Long Ashton Research Station, UK).
- Test sites are available at Bvumbwe Research Station and on nearby farms in Mtapwata Extension Planning Area (EPA).

Meeting farmer needs for early maturing beans in Blantyre/Shire Highlands

The FSIPM Project has shown that farmers want early maturity as well as yield and other characteristics in beans (Ritchie *et al.*, p. 164). There is an economic advantage for farmers in growing fast maturing beans (Orr *et al.*, 1999; Mwale, 2000).

There is a clear need to assess early maturing bean varieties (e.g. Nyadanawo and Kaulesi) alongside Mkhalira and Kambidzi under farmer management for yield and time to maturity (also time to produce leaves for relish and farmers' assessment of that). Proposals should build on the work of the Bean Improvement Programme and FSIPM Project reports: farmer assessments of *Kanthu Nkako* observation plots indicated the immediate popularity of Mkhalira and Kambidzi, largely as a result of perceived early maturity (Lawson-McDowall *et al.*, p. 138). These varieties have also been shown to have a degree of *Alectra* resistance (Mainjeni and Riches, p. 226).

In the context of efforts to increase production of desirable bean varieties, there is a need to validate and disseminate simple approaches to crop management which can increase bean yield in intercropping without reducing the yield of maize. The Mwai Wathu Womens' Group (Mombezi EPA) demonstrated the increased yield and seed quality obtainable through staking semi-climbers such as Kaulesi on pigeonpea twigs. The method was found to increase yield and cut pod disease by improving plant growth and keeping pods away from infected soil and rain splash. Farmer reaction to new varieties and crop management methods can be determined using approaches already established by the FSIPM Project.

Increasing farmer yields and profitability from sweet potato

Work by Bvumbwe Agricultural Research Station's Roots and Tubers Section in conjunction with the FSIPM Project has started farmer assessment of promising new lines grown at Bvumbwe with encouraging results (Mwale *et al.*, 1999). There is a need for on-farm assessment of the new varieties by experienced farmers to validate yields and test acceptability.

This work could be carried out with the collaboration of FSIPM Project farmers in easily accessible sites and/or farmers around Bvumbwe. Kenya should be used as the local check. Trials should compare early/late crops, *dambo* versus upland and sole cropping versus intercropping with field pea. Building on FSIPM Project experience (Mwale *et al.*, p. 48), trials should be checked for weevils and farmers encouraged to seal soil cracks if necessary to protect their investment. The value of the crop for each variety needs to be assessed against that of Kenya. Methodologies used and reported by the FSIPM Project should be used where applicable. Assessments of farmer satisfaction with yield and quality in the field and the taste of cooked product should be reassessed for comparison with the earlier data.

New product development

Some work has been done at Bvumbwe (Mwale *et al.*, 1999) which shows that sweet potato can be chipped and sun-dried on-farm to allow dry storage. When the dried sweet potato is reconstituted it makes an appetizing food (*mkaka*) which farmers enjoy. The method adds value to the crop and cuts the risk of spoilage due to seasonal oversupply while increasing food security. This could be further developed using NGO linkages for dissemination.

Development of field peas – a new cash crop

Over the lifetime of the FSIPM Project, field pea has steadily grown in importance as a smallholder cash crop, partly at the expense of relay bean which has been yielding less owing to the early termination of the rains.

Apart from the obvious importance of field pea as a food and cash crop, it has additional value to farmers in terms of green biomass for feeding to animals or for incorporation as green manure, and it has the added benefit of being a trap crop for both *Striga* and *Alectra*.

What do farmers want to achieve with this crop? What has been their experience with it? How is it grown? How do yields compare as a relay crop with/without sweet potato? How diverse is the existing planting material? What is its origin? What is the impact of *Aschochyta* (sometimes serious) and other pests and diseases and what do farmers do about it? Examine the market chain: who are end-users? Are the processors interested? These questions can be answered by interviewing FSIPM Project farmers who also provide an experienced pool of collaborators for on-farm testing of the new varieties being produced by research.

Pigeonpea pod pests

It is evident from FSIPM Project surveys of pod pests that losses are serious enough to warrant further research inputs (Ritchie *et al.*, p. 90).

Sucking bugs

Follow-up FSIPM Project work to assess pigeonpea losses due to sucking bugs. How serious is the damage? Obtain samples from dhal millers to see proportion of bug damage. What quality targets are there? Which species do most damage? What natural enemies are present (mainly egg parasitoids)? How else can farmers avoid losses (trap crops, natural enemy reservoirs, resistant varieties)?

Pod borers

Which borer species are causing most yield loss in pigeonpea? What is the link between flower damage and pod damage? How serious is the effect of flower fall due to pod borers? How do varieties react? Use Chilinga and a range of different duration varieties. Use short duration interrows to augment infestation for research on plots on-station.

Development of varieties with smooth pods or non-glandular trichomes to increase parasitoids. Use of *Crotalaria* as a borer trap crop to augment parasitoids: what effect does it have? See below.

Linkages between soil fertility improvement technologies and pest problems

Green manure technologies rely heavily on the use of various species of legumes which are grown as intercrops, relays or improved fallows within the maize intercropping system. The presence of these additional legumes has a number of potential side-effects in relation to the existing legume intercrop (pigeonpea) and successor crops. Some of these interactions are listed below. All of them can be studied simultaneously on the green manure farmer plots being maintained in Matapwata EPA for the 1999/2000 season by Mr Chanika with MAFEP funding.

Stem canker

What is the cause? How serious is it? What is the effect of *Tephrosia* on pigeonpea? This problem was found mainly in Matapwata.

Nematodes

How much effect is there when *Tephrosia* is grown with or before pigeonpea and tobacco? (ARET/USAID may be interested in the green manure risk factor.) What link is there to *Fusarium*? The problem of nematodes is discussed in more detail below.

Pod pests

What effect do *Tephrosia* and *Crotalaria* have as alternative hosts? Do they increase pest populations and/or natural enemy populations?

Whitegrubs

Does the attractiveness of incorporated *Tephrosia* to whitegrubs affect maize yields?

Nematodes and green manures

Extension materials describing the use of *Tephrosia* as a green manure warn that it should not be grown on land which is to be used for tobacco because of the danger of increasing infestations of root-knot nematodes (*Meloidogyne* spp.). However, anecdotal evidence suggests that *Crotalaria* may actually repel nematodes, although infestation levels in FSIPM Project trials have not been lowered by the presence *Crotalaria* (Chanika *et al.*, p. 256; Abeyasekera, 2000). Apart from tobacco, the main risk from increased root-knot nematode in smallholder crops is to pigeonpea.

Particular emphasis on Tephrosia

Tephrosia vogelii should be the main focus for investigations of the relationship between nematodes, green manures and crops, both because it appears particularly susceptible to root-knot infestations and also because it is emerging as the 'best-bet' green manure (Gilbert, p. 239).

Information known

There is a need to bring together and summarize the results of previous work by means of a literature review.

Information gaps?

- Varietal variation in susceptibility to root-knot nematodes among green manure species.
- Nematode infection levels on intercrops with and without green manures.
- Implication of root-knot infestation on *Tephrosia* for consecutive rotation crops (i.e. tobacco).

- Role of nematodes in *Tephrosia* 'die-back' and poor establishment in dry conditions.
- Role of green manures as trap crops for root-knot nematodes.

Need to remain focused

If *Tephrosia* manifests nematode populations but improves crop yields, it may still benefit the farmer.

Screening for resistance/tolerance

Using suitable screening techniques, green manure yields may be improved and inoculum to susceptible rotation crops may be reduced.

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Summary of group discussions

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THE WORKSHOP PROCESS

The workshop combined presentations of research findings with discussions on issues arising. Presentation sessions allowed time for discussions of the papers presented. In addition, two time slots for focused group discussions were provided on the afternoon of day 2 and the afternoon of day 4. One objective of the workshop was 'to synthesize the implications for future projects and others experience for research, extension and related policy' in relation to resource-poor smallholders livelihoods in Malawi. On day 1 of the workshop, a synthesis group was formed based on nominations from the participants. This group met in the evenings of days 2, 3 and 4 to discuss general progress in the workshop, and to develop a framework for the group discussions and for synthesis.

For the first group discussion session, topics were identified on the basis of issues raised by participants. Each participant filled in one or more cards listing an issue, and these were grouped into four areas:

- next steps for research
- dissemination of research outputs
- issues on research approaches used
- issues relating to policy, markets, seeds and varieties.

The second group session aimed to develop the ideas from the first session, with a particular focus on processes and organizational structures for technology development and uptake. In addition, one group looked into options for promoting sustainable livelihoods in the Blantyre/Shire Highlands. Individuals from the synthesis group also prepared short presentations summarizing the main lessons learned and achievements of the Farming Systems Integrated Pest Management (FSIPM) Project.

For clarity of reporting, the outputs from these synthesis activities have been summarized under the following headings.

Summary of achievements, lessons and gaps:

- achievements: research findings, capacity building and infrastructure development
- lessons: conducting participatory farming systems-oriented IPM research
- gaps and unresolved issues.

Views on the way forward:

- dissemination of research results
- further related research
- improving technology development and dissemination processes and organizations
- ideas for more sustainable livelihoods in the Blantyre/Shire Highlands.

SUMMARY OF ACHIEVEMENTS, LESSONS AND GAPS

Achievements: research findings, capacity building and infrastructure development

Research findings

- Potato crack sealing technology verified.
- Seed dressing as a control measure for whitegrubs in maize, including identification of Gaucho-T as an effective product.
- Cultural control strategies for termites based on farmer practice.
- Assessment and identification of bean cultivars under local intercropping systems.
- Assessment of improved pigeonpea varieties under intercropping smallholder systems.
- Assessment of green manure (*Crotalaria* and *Tephrosia*) for soil fertility improvement and also as a control measure for *Striga*.
- Analysis and understanding of farmers strategies for a range of important pests and diseases and for weeding options and strategies under various family conditions.
- Comprehensive synthesis of lessons on markets and livelihoods in Blantyre/Shire Highlands.
- Wider understanding of land conservation technologies.
- A comprehensive understanding of relevant approaches and methods for conducting participatory farming systems research with farmers.
- Improved understanding of farmer communication networks, farmer experimentation and farmers' suspicions and expectations.

Capacity building and infrastructure development

- Establishment of a conducive environment and understanding with local people in the project area for any future research and development projects to build on, including significant farmer capacity for collaborative research activities.
- A developed and equipped technical team with excellent capacity for IPM diagnostic and implementation activities.
- Nine staff trained to M.Sc. level, three to Diploma level, and two sent on overseas short courses; a significant contribution to the Malawi's research capacity.
- Establishment of a significant researcher capacity for understanding FSIPM concepts in the context of Malawi smallholder agriculture which will greatly benefit any future similar work.
- Construction of student hostel at Bunda College of Agriculture and renovation of the Plant Protection building at Bvumbwe Research Station underway.
- Adequate laboratory equipment in place for future IPM work.
- Pending: rehabilitation of a glasshouse at Bvumbwe Research Station with funds left over from other building rehabilitation.

Lessons: conducting participatory farming systems-oriented IPM research

- At the project design stage, there is a need for clear problem analysis with farmers and for flexibility during implementation.
- To have meaningful participation, farming systems on-farm research works well when the number of farmers is limited because of the rigour and time required.
- The farming systems research approach needs adequate time to build up the trust of farmers; at the start, farmers have suspicions and expectations.
- Developing a good understanding of the nature of technical problems also requires time and rigour in order to deal with seasonal variations of pests (e.g. termites).
- The use of indigenous knowledge is important for understanding problems, particularly if combined with researchers' knowledge.
- In dealing with pests there is a need for flexibility in approach (e.g. if a reported pest is not evidenced during monitoring, should a project go for hot spots in another area?).
- Markets are important to understand because they influence incentives for promoting technologies.
- It is important for projects like the FSIPM Project to recognize the importance of collaboration with other scientists and NGOs. This was critical for the green manure work. Such collaboration reduces duplication of effort, maximizes resource use and makes for consistency in approaches and evaluation.
- Pest management requires an integrated/holistic approach that takes account of a wide range of biophysical interactions and a complex set of decisions at plot and farm level relating to crop choice and management.
- In view of this, there is a substantial challenge in how to package IPM messages and how to disseminate these messages. This is likely to require inputs from other stakeholders, such as extension staff, NGOs and private sector players involved with input supply and marketing.

Gaps and unresolved issues

The groups which discussed next steps for research, dissemination of research outputs, and issues relating to research approaches, policy, markets, seeds and varieties identified a number of gaps and unresolved issues.

Research gaps

The group mandated to discuss research gaps covered indigenous knowledge of the control of white grubs, *Striga* and termites, biological control of the pests, management of foliar pests and diseases, and legume technology (green manure and soil fertility), all in the context of crops on which the FSIPM Project had worked, i.e. maize, pigeonpea, bean and sweet potato.

The main gaps noted from these discussions were as follows.

- Whitegrubs, *Striga*, termites – lack of full documentation of the indigenous methods used and their efficacy.
- Biological control – lack of documentation of the information available on natural enemies.
- Management of foliar pests and diseases – limited emphasis on IPM technologies.
- Legume technology (manure and soil fertility) – reasons for current low adoption of the various legume technologies developed.
- For all technologies found to be effective in the project area – a means for extrapolating the results from these small areas to larger areas.

Dissemination of research results

The group discussing dissemination noted that the following additional gaps needed to be addressed.

- Unavailability of seeds of resistant varieties.
- Unavailability of green manures.
- Reasons for delay in adoption or rejection of new technologies.

Table 1. Action points for dissemination of technical outputs on IPM

What we know	What to do	How to do it
Information on *Striga* as it relates to soil fertility	Targeted leaflets for extension Training agencies involved with extension Use of radio	Communication channels: farmers clubs farmer associations input suppliers communal gathering points, e.g. health centre, churches/mosques, youth clubs, schools, and stakeholders, e.g. NGOs
Termite damage/weed options	Targeted leaflets for extension Use of radio	As above
Use of Gaucho to control whitegrubs in maize	Consolidate research results and present to the Technology Clearing House of the Ministry of Agriculture and Irrigation	As above
Control of sweet potato weevil through 'crack sealing'		As above
Potential pigeonpea varieties for use by farmers	Consolidate research results and present to the Technology Clearing House of the Ministry of Agriculture and Irrigation	As above

Research approaches: issues and gaps

The group covering this topic identified the following issues and gaps.

- Within the limited area of operation it was difficult to explore fully hot spots for use in pest experiments, possibly due to finances – this is related to a need for more appropriate site selection approaches.
- Lack of skills in participatory research – the project document assumed certain skills would be available at the start, but these had to be developed within the project.
- Fuller integration of socio-economic and biophysical data sets – for more effective targeting and interpretation of data there is a need to integrate socio-economic and biophysical data sets during site characterization to identify distinct groups that the study would use throughout; this would help to isolate differences in livelihood strategies of the farmers by typology.
- Seasonal variation in pests and diseases – appropriate diagnostic and experimental methods for coping with seasonal variation.
- Inadequate initial problem diagnosis – the group felt that a fuller analysis of farmer problems at the start could have been undertaken and there is a need for user-friendly but effective diagnostic methods for IPM.
- Appropriate methods of on-farm experimentation – experimental methods used for specific pests are needed to produce outcomes within the specified time.
- Farmer involvement and participation in trial design.
- Methods for scaling up and extrapolating research results.
- Need to know how to link technology development and dissemination to markets.
- Extension feedback and diagnostic capacity.
- Interpretation of research results for developing clear extension material.
- Methods for measurement of adoption of IPM approaches.

VIEWS ON THE WAY FORWARD

Dissemination of research results

Group 2 proposed action points regarding dissemination of the project's technical outputs on IPM, given in Table 1.

Further related research

The ideas developed by the discussion group on future technical research topics research were refined by the project team leader into a short paper (see Ritchie, p. 292).

A number of points were made regarding the project documentation and also planning of future similar projects which are summarized below.

- Documentation of lessons: the FSIPM Project team should fully document the various participatory qualitative and quantitative research approaches used and the lessons they have learned from using these approaches. This should be done within an interdisciplinary framework, rather than each discipline working independently.

- Integrated reporting: the conclusions from the range of data sets should be brought together for a thematic summary of the project's main findings.
- Cross-disciplinary workplans: in future similar projects there is a need for cross-disciplinary workplans before implementation.
- Site selection: future similar projects should consider using pest and disease hot spots.
- Training and staff selection: future projects should engage staff with appropriate skills or give training to existing personnel in on-farm participatory IPM approaches.

Improving technology development and dissemination processes and organizations

This topic was covered mainly in the second discussion session and included problem tree analysis of the research and dissemination process and also a force field analysis of the national research and extension system. Below is a summary of the main points arising from these discussions. Some relate specifically to the FSIPM Project, but most broadly address research and dissemination in Malawi.

Technology development

Core problem – no clear vision of end-users' needs.

Causes

- Problem identification not objective (vested research interests).
- Lack of multidisciplinarity in problem identification and experimentation.
- Lack of involvement of end-users in research process (processors, farmers, consumers).
- Improper incentives for scientists.
- Researchers' culture lacks flexibility and interest in indigenous technical knowledge.
- Lack of enabling research funding policies, e.g. funding linked to clear identification of demand from users.

Consequences

- Inadequate strategic vision for project selection.
- Projects with inadequate life span to achieve impact.
- Fashion/resource-driven research which is not sufficiently responsive to farmers needs, interests and markets.
- Inappropriate technologies being developed and disseminated.
- Inadequate co-ordination between scientists.
- Poor adoption of technologies by farmers and lack of impact.
- Donors lose interest in funding research.

Comments

- There is a need to attach responsibility to individuals.
- It is difficult to reward scientists by impact.
- There is a need to revisit who will do what.
- Make action time frame.

An objective tree for improved technology development is given in Figure 1.

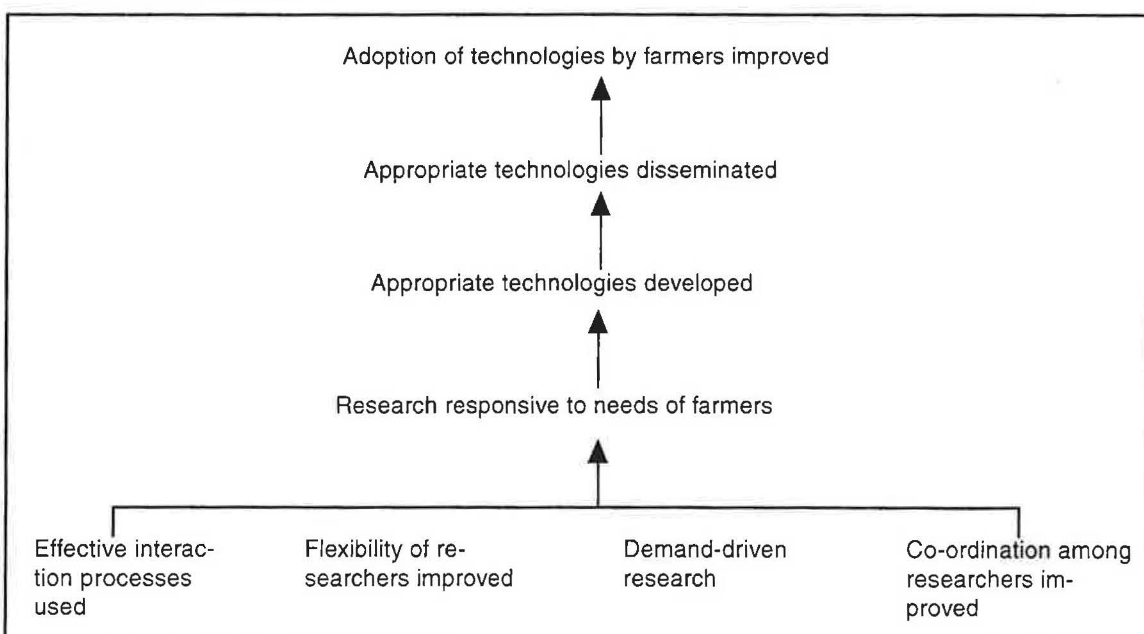


Figure 1. Objective tree for improved technology development.

Suggested action points

What to do	Who to do	When
• Effective interactive processes used – participatory research and extension methods	DARTS DAETS NGOs	Ongoing
• Flexibility of researchers improved – incorporating ITK in research	DARTS DAETS NGOs	Ongoing
• Demand-driven research strengthened	DARTS DAETS NGOs	Ongoing
• Interact with farmers through appropriate methods		
• Conduct farmer-managed trials		
• Conduct market-led research		
• Co-ordination among researchers improved	DARTS NGOs	Ongoing
• Intensify networking of researchers within and outside the country		
• Intensify sharing of information among researchers		

Dissemination of technologies

Core problem – poor adoption of technologies by farmers.

Causes

- Inappropriate technologies being disseminated.
- Lack of resources and inputs (on the part of the farmer).
- Use of inappropriate communication channels.
- Ineffective interaction processes with farmers.
- Lack of feedback, monitoring and impact assessment.
- Overloaded extension worker (working with many farmers and institutions).

Effects

- De-motivated extension personnel.
- Farmers discouraged.

An objective tree is given in Figure 2.

What to do	Who to do	When
Extension personnel to be motivated		
• Provide training in FLS to identify problem areas	DAES, DCP, NGOs	June 2000, ongoing
• Create competitive spirit in FLS through material incentives	DAES,DCP, NGOs	June 2000, ongoing
• Review bicycle allowances and timely payment	DAES	June 2000, ongoing
• Research-extension linkage to be improved – operationalize the research-extension mechanism as provided for in the booklet *Extension–Farmer Linkages*	CAETS	June 2000 and ongoing
• Strengthen on-farm research	DARTS, NGOs, DAES	2000/2001 season, ongoing
• Provide feedback, monitoring and impact assessment – participatory monitoring and impact assessment	Multidisciplinary monitoring committees at CAETS, ADD, RDP, NGOs, Researchers and farmers	June 2000, ongoing

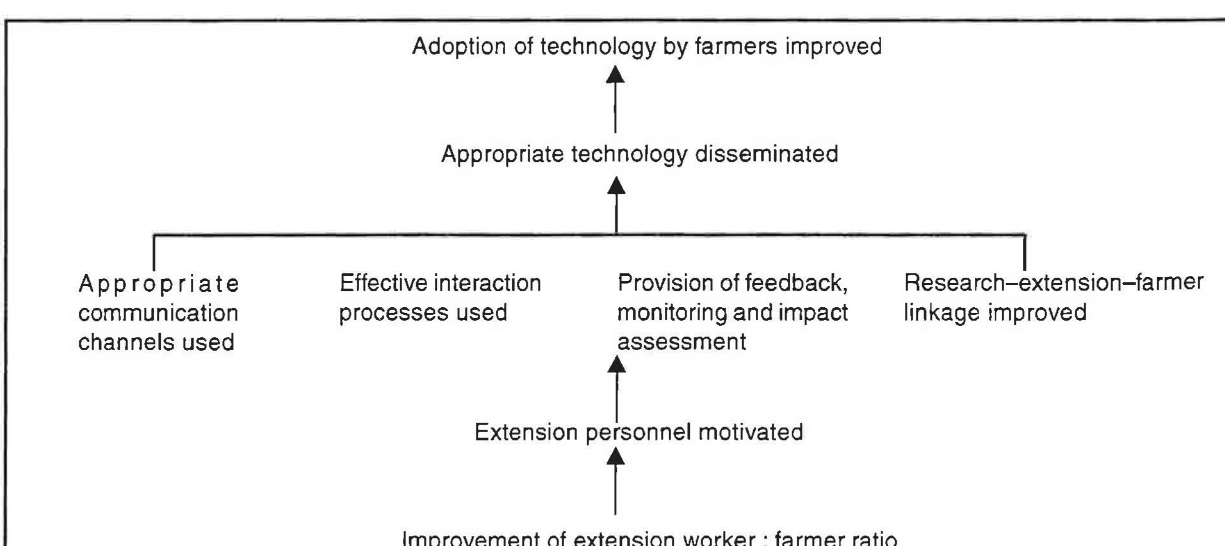


Figure 2. Objective tree for dissemination of technologies.

What to do	Who to do	When
• Documentation of feedback	DAETS, researchers, NGOs	June 2000, ongoing
• Effective interactive processes used – adopt approved interactive and appropriate processes: FFS, PRA, PEM, VLPA, Theatre for Development	DAETS, NGOs	Ongoing
• Appropriate communication channels used – identify appropriate communication channels and operationalize their uses: interested groups, PEM, Theatre of Development, FFS		

Suggested improvements relating to policy and markets

Input/seed supply

- Allow for voluntary registration of varieties.
- Create a wider range of crop and variety options for farmers.
- Adjust and use regulations to focus on quality, rather than trying to control supply.
- Take measures to minimize the extent to which donor and government-funded input supply programmes undermine private sector initiatives.

Markets

- Strengthen marketing in remote areas.
- Provide more market information for farmers and traders.
- Promote farmer organizations so that farmers secure higher prices.
- Infrastructure development to open up new market opportunities and lower existing transaction costs.

Force field analysis of national research and extension system

Main players	National and local	International
Technology development agents	DARTS, Fisheries, ARET, FRIM, TRF, ILLOVO, Bunda College, seed and chemical companies	CG centres: ICRISAT CIMMYT, ICRAF, CIAT, seed companies
Technology adaptation agencies	Government extension agents, NGOs, farmers seed and chemical companies	Seed and chemical companies
Dissemination	Farmers, traders, NGOs, government extension, mass media	Seed and chemical companies

The force field analysis (Figure 3) concentrated on the role of the national institutions, mainly the public sector ones.

Actions suggested to address negative forces

- Establish mechanisms for improved communication between researchers and markets, e.g. electronic connections (web site), formal links with producers and processors associations, individual contacts.
- Secure budget line for infrastructure and equipment.
- Conduct review on advocacy and marketing of research capacity.
- Provide training in: proposal/report writing, convincing clients (e.g. NGOs), cost-recovery, business orientation.
- Strengthen deficit areas in technical competence.
- Remuneration of public sector research and extension to be related to productivity and level of competence not just salary scales, qualifications and years of service.

Ideas for more sustainable livelihoods in the Blantyre/Shire Highlands

Problems

- Low productivity.
- Limited land.
- Poverty.
- Hunger.
- Low income/lack of capital.
- Erratic rainfall.
- High cost of inorganic fertilizer.
- Inadequate infrastructure.
- High population.
- Low soil fertility.
- Poor health.
- Poor communication.
- Environmental degradation.
- High illiteracy.
- High dependence rate.
- Early marriages.
- Pests and diseases.
- Theft/insecurity.
- Labour shortage.
- High unemployment.
- Roaming livestock.
- Lack of credit facilities.
- Unavailability of, and accessibility to, inputs.

Desired situation (in 5–10 years)

- Market-orientated research supported by operational market intelligence units
- Sustainable funding levels
- Motivated workforce and adequate research capacity
- Strong research – extension – farmer linkage
- Revised masterplans in line with market orientated research approach with clear milestones identified,
- Active participation and contribution by the private sector in research
- An effective network for marketing and communicating

Positive forces

- Existing effective public-private sector partnerships: e.g. seed companies, maize research programme and smallholder farmer (client for flint maize varieties)
- OPV seed multiplication schemes operating
- Small seed companies started by entrepreneurs
- Farmer marketing associations emerging
- Policies supporting participatory approaches
- ADD evaluation units and crop estimates
- Training opportunities exist
- Agricultural graduates available

Negative forces

- Limited funding for infrastructure – roads and markets
- Inadequate research and extension infrastructure, particularly information and communication systems
- Researchers limited vision of where to go
- Industry and traders not proactive in setting research agenda
- Limited access by researchers to top people in industry
- Negative views of the adaptive research experience – seen as slow and expensive
- Loss of researchers to NGOs giving higher rates of remuneration

Current situation

- Production-orientated research
- Low levels of funding and poor incentives for staff
- Human resources not well developed
- Poor infrastructure
- Master-plans for research inadequately implemented
- Weak research – extension – farmer linkage
- Lack of linkage to market intelligence (MIPA, APRU, private sector) for all crops except tobacco, tea, coffee, cotton
- Weak advocacy/marketing skills within research and extension communities for both national and international opportunities

Figure 3. Force field analysis.

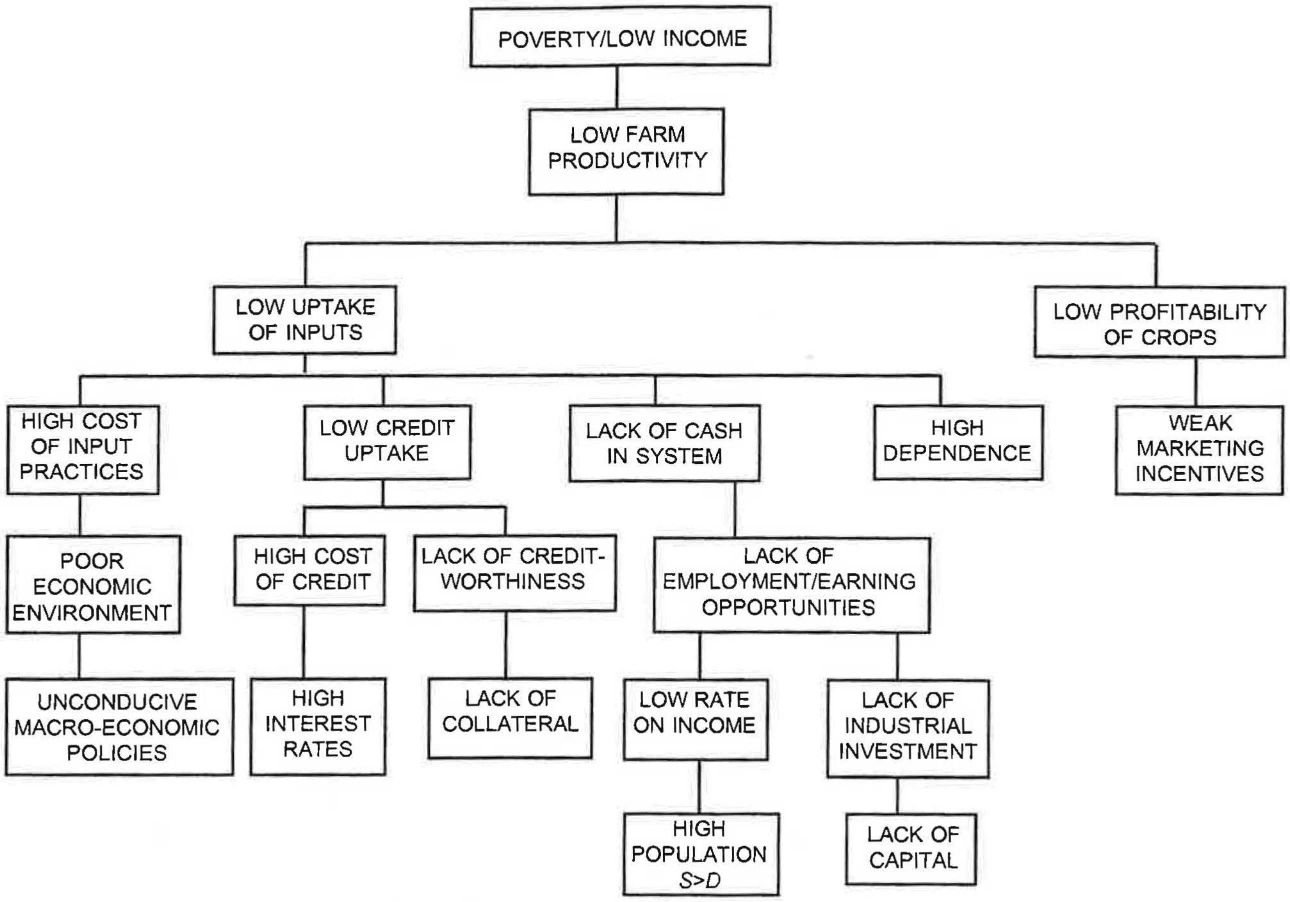


Figure 4. Problem tree: technical analysis of low farm productivity.

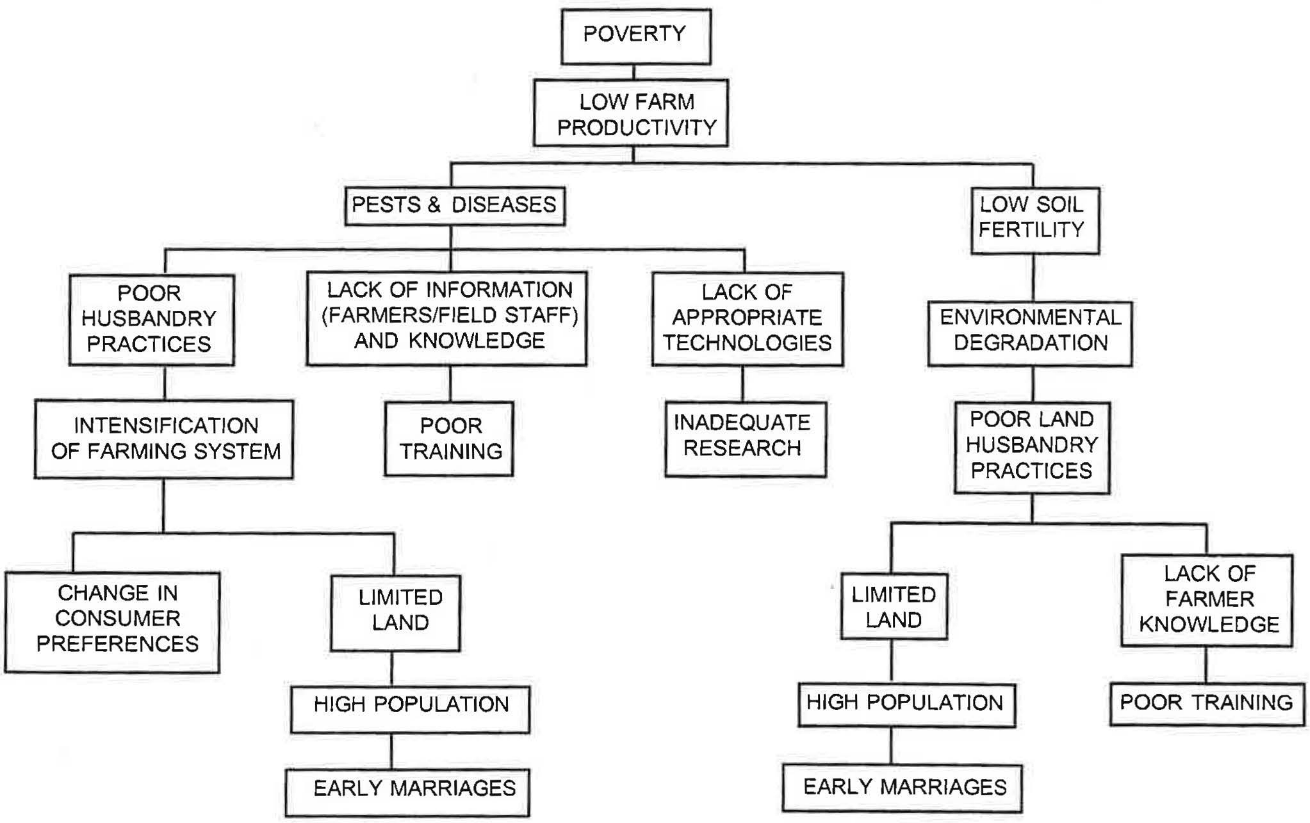


Figure 5. Problem tree: policy and economic aspects of low farm productivity.

Possible actions for improved livelihoods and responsibilities are set out in Table 2.

Table 2. Actions for improved livelihoods and responsibilities

Problem	Actions to address problem	Responsibility	Time
Pests and diseases	Teach farmers appropriate cultural/ husbandry practices	Extension staff, NGOs	Ongoing
	Provide extension leaflets for extension staff and farmers on various pest management strategies	Extension staff	Before March
	Rigorous research on strategies for pests without clear recommendations	DAR	Before next season
High illiteracy rate	Teach farmers through drama, radio, etc.	Farmers, NGOs, extension staff	Ongoing
	Encourage attendance of children at school	Farmers' drama groups, extension staff, NGOs	Ongoing
Low soil fertility	Promote low cost organic manure technologies	NGOs, extension staff, researchers	Ongoing
Low use of inputs	Create markets to improve income for poor farmers	Extension staff, NGOs, researchers	Ongoing
	Encourage private sector participation in the marketing of agricultural products	NGOs, private institutions, farmers associations	Ongoing
	Empower farmers through formation of co-operatives/clubs/organizations	NGOs, extension staff, donors, farmers	Ongoing
	Encourage production of high value crops such as vegetables	Extension staff, farmers	Ongoing
Poor infrastructure	Encourage community self-help initiatives	NGOs, extension staff, community development field staff	Ongoing
	Food for work programmes (safety nets)	Donors	Ongoing
Poor health	Encourage kitchen gardens	Extension staff/ NGOs	Ongoing
	Promote vegetable production	Extension staff/ NGOs	Ongoing
	Encourage good hygiene	Health field staff/social welfare field staff	Ongoing
Low profitability of crops grown by small farmers	Create markets to improve income for poor farmers	Extension staff, farmers, NGOs	Ongoing
	Encourage private sector participation in the marketing of agricultural products	NGOs, private sector	Ongoing
	Empower farmers through formation of co-operatives/clubs/organizations	NGOs, extension staff	Ongoing
	Encourage production of high-value crops such as vegetables	Extension staff, NGOs	Ongoing

Issues arising from the field trip to the ICRISAT best-bet technologies mother trial

C. Chiumia-Kaunda

Farming Systems Integrated Pest Management Project, PO Box 5748, Limbe, Malawi

Workshop participants visited one of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) mother trials in Nsanyila village, near Mangochi in Nasenga EPA on the afternoon of 1 December 1999. The farmer gave a presentation to the group describing the trials that had just been harvested for the 1998/99 season.

The trial design comprised four blocks of 36 plots occupying half an acre in the following combinations.

1. Unfertilized plot
2. Maize + 35 kg N/ha fertilizer
3. Maize with pigeonpea or bean
4. Rotation – soyabean, groundnut, bean
5. Maize phase of green manure rotation
6. Undersown green manure (*Tephrosia vogelii*)
7. Improved 1-year fallow
8. Maize/groundnut + fertilizer
9. Maize phase of 1-year fallow

The objective of these on-farm trials was to improve soil fertility and so encourage farmers to use pigeonpea as a soil improvement crop. Varieties of pigeonpea used included ICP9145 in seed multiplication trials and 0020 in the trials.

RESEARCH ISSUES

Farmer practice vs research recommendations

According to the trial design, *Tephrosia* was planted 2 weeks after planting maize which the farmer believed was too late for the viability of the *Tephrosia* crop. As such, the crop had failed for two seasons. The farmer, however, had planted a few seeds at the time of maize planting to prove to researchers that *Tephrosia* can survive if planted at this time. The farmer considered that using *Tephrosia* will lead to a gradual increase in soil fertility. He had seen hedgerow planting with *Tephrosia* elsewhere but was unable to try it himself due to a lack of seed.

Striga problem

It was the farmer's practice to dig up *Striga* plants just after flowering.

Termite problem

A large termite mound was observed in the experimental area. According to researcher recommendations, trials are not supposed to be carried out near mounds. It was learnt from the farmer that the mound had developed during the course of the trials and termites became a problem. The farmer unsuccessfully applied Sevin (carbaryl), a chemical that is usually applied to cotton plants for control of other insect pests. However, the visiting group wanted to know why the farmer did not destroy the mound as the source of the problem. The farmer replied that at the right time termites can be beneficial because they help in the biodegradation of crop residues and for this reason he could not destroy the mound.

How farmers quantify yields

Before taking part in the trials, the farmer used to harvest two baskets of maize from half an acre of land compared to 12 x 50 kg bags harvested after the trials.

Farmer selection

Interested farmers were asked by the village chief to register and collect seeds for trials. Ten farmers registered but only a few took part in the trials. No reason was given for those who changed their minds.

Dissemination

Ten farmers had adopted from the trial farmer the system of growing maize/ groundnut and maize/pigeonpea intercrops. However, no farmer was currently interested in growing *Tephrosia* because they had seen that it had failed. This implies that farmers will adopt a technology if they see it to be effective.

Farmers' main problem

The farmer indicated that his main problem was livestock, especially goats, attacking his crops. He had constructed a fence around his garden from *nakuka* tree branches that are resistant to termite attack. This was contrary to researchers rating of farmers' problems who considered soil fertility to be the major concern.

DISCUSSION

D. Coyne. Information from farmers' own experimentation is useful, but their experimentation with chemicals is a concern as a potential health hazard. What information does the farmer have on the dangers? How well is the system accommodated to deliver this information? Should the delivery of this information be prioritized?

C. E. D. Mainjeni. I think that one of the best ways to promote the safe use of pesticides is to have regular or ongoing training on the dangers of pesticides to human health and to the environment. Various methods, for example, radio, newspapers, drama, newsletters, informal training, discussions and the help of local leaders and innovators, can all be used to disseminate this information.

J. Lawson-McDowall. Radio is an ideal medium for information about dangerous pesticides to reach farmers. Pesticides are primarily bought and used by men and men listen to the radio a great deal.

V. Kabambe. The problem of farmers experimenting with pesticides without safety guidelines stems from over protection from the authorities. Researchers are constantly told that farmers cannot afford pesticides. Therefore, researchers fail to identify or provide information on alternative pesticides, rates and timings. When farmers have a dire need to protect their crops they have no options or guidelines. This was the case here. No-one has experimented with controlling termites by using some of the biodegradable pesticides on the understanding that farmers cannot afford them. In the end, even the researchers failed to identify a strategy for managing pests in trials.

G. K. C. Nyirenda. Sevin is used for control of some cotton pests but it is not recommended for termite control. The farmer was using Sevin out of desperation. There is a draft legislation which has not yet passed through parliament. This act will contribute considerably to the control of wanton use of pesticides especially if it is combined with the dissemination of information on the proper use of pesticides.

C. S. M. Chanika. While it is true that farmer education is important to reduce the trading of unregistered chemicals, it is essential that the pesticide act is passed because if, after educating farmers, the sale of unregistered chemicals persists, no action can be taken against traders dealing in dangerous chemicals.

F. M. T. Gondwe. When farmers experiment as here, should this information not be used in future research. If Sevin is used in experiments on whitegrubs by farmers (FSIPM Project), or on termites (ICRISAT), or if Temic is tested on tomato (Bvumbwe Research Station), should immediate research not be carried out to evaluate this chemical use?

B. Mwale. World Vision International links farmers with Rab Processors for marketing of pigeonpea, demonstrating the key role of NGOs in facilitating a market environment for farmers.

Closing remarks

H. L. Potter

Natural Resources Adviser, Department for International Development (DFID), Lilongwe, Malawi

I have listened with interest to the presentations of the various groups in which future approaches to research have been discussed. However, you should all be aware that next year will see considerable changes in the way that work is funded within the DARTS. The institution's core budget will not be renewed. In future, research work needs to be responsive to market forces, consequently funding will be made through individual contracts for projects. These contracts will also have to include financing to cover the overheads of the institution. This approach places more emphasis on individual skills and initiative.

In his presentation, Dr Ritchie outlined appropriate and important areas for future research. During the group discussion we heard of constraints on future research but also heard of positive actions that could overcome these to make progress in the future. However, these will remain as a nice 'wish list' if action plans are not developed. An action plan is essential in developing proposals for future work with its accompanying funding. The following summary shows the essential components of a credible action plan.

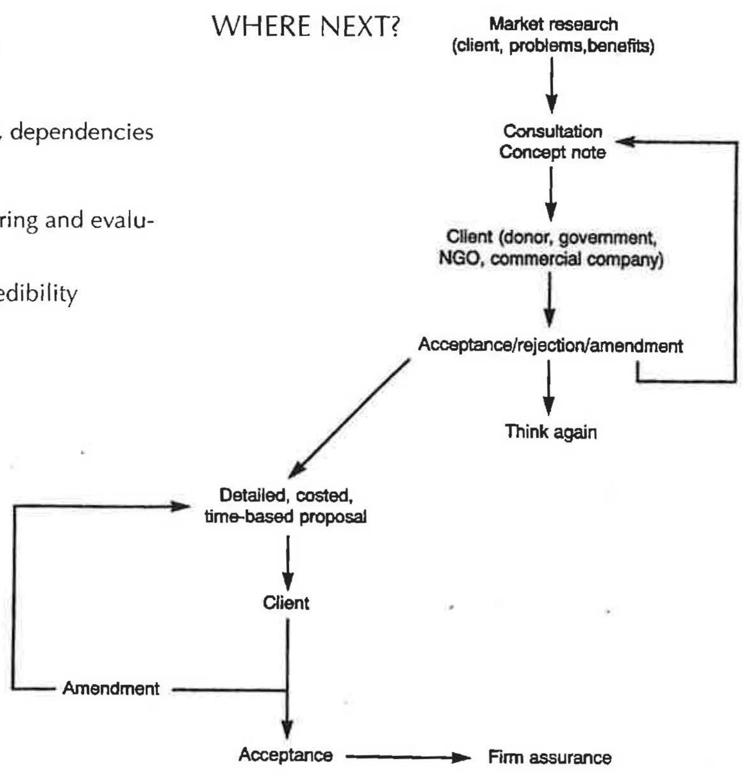
ACTION PLAN

A	Activities	to achieve objectives
C	Cash	grant, loan, contract
T	Time	schedule of activities, dependencies
I	Institutions	lead, partnerships
O	Organization	participation, monitoring and evaluation
N	News	awareness, raising credibility
P	People	skills, multidisciplinarity, incentives
L	Location	where work carried out, local/regional/national
A	Alternatives	consider all possibilities, review past work
N	Next	what to do afterwards, monitor work, where to now?

Malawi is not lacking the skills, with the possible exception of social scientists, to carry out effective research. There is a need, however, for improvement in administration and in cross-disciplinary thinking and activities – you need to be multidisciplinary in your minds as well as in your projects.

The FSIPM Project will finish at the end of March 2000 and the research results will be written up and disseminated. Proposals for research work after March 2000 can now start to be developed as described below. DFID will be pleased to receive for appraisal convincing proposals which will hopefully produce effective and productive co-operation in the years to come.

WHERE NEXT?



Glossary

Arhar dhal	pigeonpea after splitting and dehulling
Bwanyula	laying stripped-off bottom leaves of maize plants in the furrow, then covering them with soil from the old ridges to create a new ridge for planting a relay crop
Chinamwali	initiation ceremony
Chipere ganyu	exchange labour
Chiperoni	sporadic showers
Dambo	low lying land
Dimba	irrigated vegetable garden
Ganyu	hired labour
Geni	small-scale enterprise
Kachasu	local gin
Kantha nkako	'our own thing'
Kanyenya	fried
Kapinga	weed
Kubandira	practice of covering the weeds by soil drawn from the furrow to rebuild adjacent ridges and support the plants
Kucheza	chat
Kukawa	loss or mysterious reduction in yield
Kukwezera	weeding technique that reduces damage from termites
Kunyala	wilting
Kupala/Kukhwazira	practice whereby weeds are scraped from the side of the ridge without moving the soil and leaving the weeds to dry
Kupalira	hand hoe weeding by scraping the sides of the two ridges and spreading the weeds in the weeded intervening furrow to dry them out
Kupininga	casting of spells
Kusenda/Kuwojekera	hand hoe weeding whereby weeds from the side of one ridge are hauled downwards from the maize planting station and transferred and buried on the side of the next ridge
Kuwerenga ganyu	piecework agricultural labour
Kuzulira	pulling up tall weeds by hand and scraping off smaller ones from the sides of the ridge with a hoe without disturbing those weeds in the furrow; the scraped weeds are then laid on top of the adjacent ridge
Madeya	bran from maize, substitute for ufa or maize flour
Makaka/Mkaka	dried chipped sweet potato tubers (or cassava) which can be stored and later reconstituted and cooked by boiling in water
Mbumba	cluster of related households
Mbwera	relay crop
Munda	upland
Nakafumbwe	sweet potato weevil damage
Nkokwe	maize granary
Nsima	thick porridge made from maize flour
Thandize	communal labour
Thangata	forced labour
Toordhal	processed pigeonpea
Tur	pigeonpea
Tuver	pigeonpea
Ufa	flour made from fully ripened maize
Zophikaphika	cooked/cooked foods

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADD	Agricultural Development Division
AHI	African Highland Initiative
ANOVA	analysis of variance
APSIM	agricultural production simulation modelling
APSRU	Agricultural Production Systems Research Unit
BCR	benefit–cost ratio
BIP	Bean Improvement Programme
CBA	cost–benefit analysis
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Center for the Improvement of Maize and Wheat
CT	Commodity Team
CU	Concern Universal
CV	coefficient of variation
DAP	days after planting
DARTS	Department of Agricultural Research and Technical Services
DFID	Department for International Development
EPA	Extension Planning Area
FA	field assistant
FAQ	fair average quality
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field school
FGD	focus group discussions
FP	farmer practice
FPR	farmer participatory research
FSIMP	farming systems integrated pest management
FSR&E	farming systems research and extension
GIS	geographical information system
GMA	gross margin analysis
GR	gross return
GTZ	Deutsche Gessellschaft fur Technische Zusammenarbeit Gmbh
IAR	Institute of Agricultural Research
ICIPE	International Centre for Insect Physiology and Ecology
ICM	integrated crop management
ICRISAT	International Crops Research for Semi-Arid Tropics
IFSP	Integrated Food Security Programme
IITA	International Institute of Tropical Agriculture
IPM	integrated pest management
LGB	larger grain borer
MAFE	Malawi Agroforestry Extension
MGPPP	Malawi–German Plant Protection Project
MoAI	Ministry of Agriculture and Irrigation
NARS	national agricultural research system
NGO	non-governmental organization
NRI	Natural Resources Institute
NRG	Natural Resources Group
ODA	Overseas Development Administration
POP	persistent organic pollutants
PRA	participatory rural appraisal
ROVC	returns over variable costs
RDP	Rural Development Project
RMP	Risk Management Project
SACA	Smallholder Agricultural Credit Administration
SAFGRAD	Semi-Arid Food Grain Research and Development
SPG	seed producer group
TA	Traditional Authority
TEP	total extractable polyphenols
T&V	training and visit
TVC	total variable cost

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