# PERSPECTIVES ON PESTS II

Achievements of research under
UK Department for International Development
Crop Protection Programme
2000–05

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Natural Resources International Limited

The Department for International Development (DFID) is the UK Government Department responsible for international development policy and managing sustainable development programmes with poorer countries. The Government is committed to halve, by 2015, the proportion of the world's people whose income is less than one dollar a day; the proportion of people who suffer from hunger, and the proportion of people who lack safe drinking water. Other associated targets include basic health care provision and universal access to primary education. DFID works in partnership with the governments of developing countries, international organisations, voluntary bodies, the private sector and the research community.

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Production of this publication was funded by the DFID Crop Protection Programme for the benefit of developing countries. The views expressed are, however, not necessarily those of DFID.



SWEETMORE, A., KIMMINS, F. and SILVERSIDE, P. (2006) *Perspectives on Pests II: Achievements of research under UK Department for International Development Crop Protection Programme 2000–05*. Natural Resources International Ltd, Aylesford, UK. 206+xvi pp. ISBN: 0-9546452-7-8



Typeset by: Sweetmore Publishing Projects, Witney, Oxon, UK
Printed by: Pragati Offset Pvt. Ltd. (www.pragati.com)

Cover design by: Christel Blank, Green Ink, UK (www.greenink.co.uk), Cover photograph: Eliaineny Minja, Centro Internacional de Agricultura Tropical (CIAT), Selian Agricultural Research Institute (from project R7965, Promotion of IPM strategies for major insect pests of beans in hillsides of eastern and southern Africa).

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# Preface

Agriculture is recognised to be a key part of the UK Department for International Development (DFID)'s efforts to reduce global poverty and achieve the Millennium Development Goals[1]. It extends into areas of development policy, including food security, social protection, governance and trade. Technology is central to accelerating growth in DFID's target countries, and DFID has supported research that tackles some of the most urgent developmental constraints in agriculture, as well as other areas of natural resource management, engineering and health. Many of these sectors have pioneered new ways of working to enhance research uptake, as well as producing excellent science. The Renewable Natural Resources Research Strategy (RNRRS) programmes from 1995–2005 (extended to 2006), for example, combined high-quality natural and social science research, developed capacity in Africa, South Asia and Latin America, and disseminated their findings widely to policy makers as well as end-users. The Crop Protection Programme (CPP), the largest of the RNRRS programmes, encouraged partnerships with a broad spectrum of stakeholders and new entrants, including NGOs and the private sector, to ensure that cost-effective and environmentally sustainable crop management solutions were accessible to poor farmers. CPP project clusters were also encouraged to foster regional cooperation, as major crop pests and diseases rarely respect national boundaries and often require control in areas remote from where pests are likely to have the greatest impact.

*Perspectives on Pests II* contains profiles of research funded by DFID's Crop Protection Programme between 2000 and 2005. The first volume, published in 2001, described the earlier research achievements on the crop pest and disease constraints that affect poor farmers and consumers. This volume focuses on the approaches used to disseminate research methods and to influence policies and/or institutions. The scene-setting introduction by Blackie and Ward (page ix) usefully draws together lessons learned from the CPP, and highlights the impact of CPP research efforts to date. Although the timetable for research to achieve impact can be lengthy and unpredictable, there is already evidence that the CPP outputs are contributing to local and regional food security and providing nutritional and other livelihood benefits to a wider constituency, including poor consumers. The CPP is therefore well placed to contribute to the delivery of the Millennium Development Goals by 2015.

An independent review of the approaches used in the RNRRS[2] concluded that "Much valuable work has been carried out by the RNRRS which will continue to have many favourable consequences, even if direct poverty-reducing impact is difficult to attribute to the research. DFID's current policy of funding a 'facility' to add value to this massive resource is certainly supported by the findings of this review." The DFID 'facility' or programme forms part of the new DFID agricultural strategy, which starts in May 2006. It will scale out the most promising RNRRS outputs, which can contribute to sustained growth and poverty reduction in Africa and South Asia. Evidence of the impact of project activities will be collected, and lessons learned, in order to develop a coherent research and development policy for agriculture and natural resource management. We anticipate that selected CPP technologies with the greatest potential for impact on poverty reduction and economic growth will be scaled out through this process. In this way, they will continue to have an impact on improving the livelihoods of some of the most disadvantaged communities.

As this is the last publication from the CPP, it is appropriate to thank all those who have contributed to the programme since 1995, especially the many project partners who have carried out the work with unfailing enthusiasm and dedication under difficult or uncertain circumstances. Special thanks are due to the programme managers who designed the CPP strategy, especially Simon Eden-Green, Jill Lenné and Anthea Cook; Andrew Ward who translated their vision into a dynamic and successful research programme; the Programme Advisory Committee members, led by Professor Michael Claridge, who provided an unparalleled range of crop protection and social development expertise; and Kerry Albright and Benedikte Siderman-Wolter for leading the CPP policy and communication strategies. The support provided by Isabel Carballel and Christine Wheeler has been appreciated by project leaders, and their ability to organise the managers on financial and logistical issues has underpinned the entire programme.

Once again, the management team is grateful to the main editorial team for their tireless efforts in producing this record of CPP achievements: to Anne Sweetmore for compiling the project profiles from project technical reports, assembling images and graphics to illustrate the publication and setting the text, and to Penny Silverside for editing them assiduously and maintaining her high publication standards. They have been ably assisted by Sue Hainsworth in editing and checking the final draft and the team at Green Ink in keeping the publication on course to meet deadlines.

*Frances Kimmins*
*February 2006*

1. Millennium Development Goals: www.un.org/millenniumgoals

2. RATH, A. and BARNETT, A. (2006) *Innovations Systems: Concepts, Approaches and lessons from the RNRRS.* RNRRS synthesis study. The Policy Practice Ltd, UK.

# Editors' note

Thanks to all project collaborators who provided photographs – images are credited only where they were provided by someone other than the project collaborators.

Photo credits for 'Green Evolution': page xi, Benedikte Siderman-Wolter; page xii, Kerry Albright; page xiv, André Devaux.

If any photographs have been wrongly credited, or credits have been inadvertently omitted, please accept our apologies.

Tradenames for pesticides or biocontrol agents may be Registered or Trade Mark; tradenames are signified by an initial capital.

Due to space limitations, only selected publications are listed for each project; where a publication has more than six authors, only the first three are named.

# Glossary

| | |
|---|---|
| **Aman; T-Aman** | rainfed rice in monsoon season (T-Aman = transplanted Aman) (*see* Rice ecotypes) |
| **Aus; T-Aus** | rice direct-seeded and transplanted under rainfed and/or irrigated conditions (T-Aus = transplanted Aus) (*see* Rice ecotypes) |
| **Basidiospore** | a spore produced by fungi of the Basidiomycetes |
| **Boro** | irrigated rice grown in the rabi season (*see* Rabi; Rice ecotypes) |
| **Cestodes** | parasitic flatworms (tapeworms) that live in the digestive tracts of vertebrates as adults and often in the bodies of various animals as juveniles |
| **Cherelle** | a young cocoa bean that ripens into a pod |
| **Conidiophore** | simple or branched fungal hypha from which conidia are produced (*see* Conidium) |
| **Conidium** (plural: conidia) | type of asexual fungal spore |
| **Cultivar** | a plant variety or landrace that is in cutivation |
| **Deletion** | a gene deletion is a genetic mutation in which a part of a chromosome or a sequence of DNA is missing |
| **EurepGAP** | an initiative of retailers belonging to the Euro-Retailer Produce Working Group (Eurep), a partnership of agricultural producers and their retail customers aiming to meet accepted standards and procedures for the global certification of Good Agricultural Practices (GAP) |
| **Genotype** | the specific genetic make-up (specific genome) of an individual, usually in the form of DNA |
| **Haulm** | stalk of groundnut, bean, etc. |
| **Haustorium** (plural: haustoria) | the hyphal tip of a parasitic fungus or of the root of a parasitic plant (such as in the broomrape family), which penetrates the host's tissue, but stays outside the host cell membrane |
| **Horizontal transmission** | (of biopesticides) – spores from dead insects can infect new insects (also known as secondary cycling) |
| **Hybrid** | product of a cross: this may be between populations, breeds or cultivars of a single species; may also be between different species within the same genus (interspecific hybrids; between different subspecies within a species (intra-specific hybrids); between different genera (intergeneric hybrids) |
| **Intron** | section of DNA within a gene that does not encode part of the protein that the gene produces, and is spliced out of the mRNA that is transcribed from the gene before it is translated |
| **Kairomone** | a chemical emitted by one species that attracts a different species (*cf*: Pheromone) |
| **Landrace** | a race of plants ideally suited for the land (environment) in which they grow; they often develop naturally with minimal assistance or guidance from humans (or from humans using traditional rather than modern breeding methods) |
| **Occlusion bodies** | granuloviruses are contained (occluded) in ovicylindrical bodies (approx. 0.3 x 0.5 μm). The occluded form of nucleopolyhedroviruses is polyhedral in shape (approx. 0.15–15 μm). The occluded form of both viruses can clearly be seen using a light microscope |
| **Outgrowers** | smallholders who supply vegetables to commercial markets within and outside Kenya |
| **Pheromone** | substance secreted by an organism to affect the behaviour or development of other members of the same species; sex pheromones that attract the opposite sex for mating are used in monitoring certain insects (*cf*: Kairomone) |
| **Push–pull** | strategy for management of cereal stem borers in maize-based farming systems in Africa, developed by ICIPE and partners. The stimulo-deterrent diversionary strategy uses trap- and repellent plants: stem borers are repelled from the main crop (maize) and simultaneously attracted to a trap plant (Napier or Sudan grass) |
| **Rabi** | post-rainy season when crops are grown on residual moisture or irrigation |
| **Rice ecotypes** | seasonal rice ecotypes are grown in Bangladesh and the Bay of Bengal in India: Boro (March–May); Aus (July–August); transplanted Aman (T-Aman) (December–January, shallow water); and broadcast Aman (B-Aman) (December–January, deep water). Most of the rice varieties planted belong to *indica* sub-species, although some authors consider that the Aus and Aman rice varieties belong to a special group |

| | |
|---|---|
| **Roguing** | removal of diseased plants from a field |
| **Sclerotium** (plural: sclerotia) | compact mass of hardened mycelium that serves as a dormant stage in some fungi |
| **Seed priming** | method by which seed is first soaked then dried back to its original water content. Priming advances germination by inducing biochemical changes in the seed, the products of which persist following desiccation and are available quickly once seeds are re-imbibed |
| **Stakeholders** | a broad grouping of individuals, groups or organisations with an interest in, or influence over, a programme or project |
| **Synnema** | group of conidiophores bearing conidia on the apex/sides (*see* Conidium; Conidiophore) |
| ***Trichoderma*** | genus of fungi used as biological fungicides |
| **Trichomes** | on plants, are epidermal outgrowths of various kinds (e.g. pods of *Mucuna* are covered with dense, stinging hairs or trichomes) |
| **Variety** | an identifiable strain within a species, usually referring to a strain that arises in nature as opposed to a cultivar specifically bred for particular properties; sometimes used synonymously with cultivar |
| **Vegetative flush** | climate-related onset of bud and leaf growth |
| **Volatiles** | compounds that vaporise at normal temperatures and pressures |

# Green Evolution – partnerships and progress for change

## INTRODUCTION

In the 1960s, the concept of triage amongst developing countries was actively being discussed (Paddock and Paddock, 1967). They argued that a population–food collision was inevitable. With science unable to offer sufficient increases in agricultural production, the hungry nations of the 1960s would inevitably become the starving nations of the 1970s. Their solution – which was presented in the name of reason, US self-interest and true humanitarianism – was a famine–disaster version of the military medical 'triage' system. The USA needed to divide the developing nations into three categories:

- those so hopelessly headed for, or in the grip of, famine (whether because of overpopulation, agricultural insufficiency or political ineptness) that aid would be a waste; these 'can't-be-saved nations' would be ignored and left to their fate (examples included India, Egypt and Haiti)
- those who could survive without aid, 'the walking wounded' (the Gambia, Libya)
- those who could be saved with help (Pakistan, Tunisia).

The deeply disturbing Paddock scenario did not come about – and the reason is largely that they, in common with other influential voices, underestimated the power of science. In India alone, wheat production increased sixfold from the 1960s to today; rice yields more than doubled; and the percentage of undernourished people fell from 38 to 21% (Rashid *et al.*, 2005). This was the celebrated 'Green Revolution'. The model focused on improving the productivity of cereals through the development of crop varieties that could exploit intensive cropping systems. It was a child of its time – capital-intensive, hierarchical, and based on the Schultz hypothesis of disruptive, rapid change to make things happen in what were perceived as deeply conservative peasant societies.

But, while there have been many and obvious gains from the Green Revolution, it has not been a universal solution – most notably in Africa, but also for many marginalised groups in Asia and South America. The Schultzian 'big bang' approach, relying on the Asian combination of improved seeds and enhanced fertility management, was not sufficient to bring about needed change and the Green Revolution failed to take root. These farmers face harsh conditions, their land is degraded and rainfall is unreliable. Crop yields are low. High transport costs make it difficult to compete in agricultural export markets, and rising international and local fertiliser prices make this essential input unprofitable to use except on very high-value crops, which are typically too risky for the poor to grow. Consequently the poor (some 80%+ in the case of Malawi) become poorer, their food supplies dwindle, and national growth stalls. At the same time, the AIDS pandemic causes suffering and death in almost every family.

## A GREEN EVOLUTION STRATEGY

The stalling of the Green Revolution, particularly in Africa, has led to a decline in support for agricultural research and interventions that address agricultural productivity. The evidence is overwhelming that the change needed in difficult agricultural environments (much of sub-Saharan Africa) will not come from a fairytale, single-focus intervention. However, there is an alternative approach that builds on the evolving partnership of scientists, farming communities and development agencies (both private and public). This 'Green Evolution' approach encourages the efficient and swift transformation of agricultural production through harnessing the best of skills in a collaborative, 'learning by doing' manner, in which all feel ownership and pride. Existing structures are improved and enhanced to build change through an evolutionary rather than a revolutionary approach. This is cost-effective, brings the best of developing country and international expertise together in a problem-solving format, and can (as the examples cited in this publication demonstrate) be rapidly scaled up to reach the poor quickly and effectively. Unlike the hierarchical and prescriptive nature of the 'big bang' revolution, an evolutionary strategy uses multiple channels and players, and allows choices to emerge and be tested, and the best to be adopted. It fits comfortably into the widely adopted participatory framework for development that facilitates the empowerment of the poor and disadvantaged. The Green Evolution, in common with evolution in nature, is efficient in selecting the best and encourages partnership and collaboration.

A Green Evolution strategy involves many simultaneous interventions by multiple players, and is based around the highly efficient use of the right inputs used in the right way. This creates broad-based opportunities for the poor to benefit directly from effective access to the improved seed, fertilisers and other critical inputs that are the foundations of essential growth in productivity. Such a strategy, with a foundation of good science, directed by farmers' needs and informed by the commercial, social and ecological environments of the continent, can provide gains not only for the better-off producers, but also for the poor and excluded.

## NEED FOR CONSISTENCY, RELIABILITY AND EFFICIENCY

DeVries and Toennissen (2001) set the scene graphically:

> "It is that of a single mother whose primary means of income is a one hectare plot of unimproved land on an eroded hillside ... From each harvest she must provide for virtually all the needs of her family throughout the year, including clothing, health care, education costs and housing. Because she can afford few purchased inputs, the yield potential of her farm is low ... perhaps 2000 kilograms of produce ... In the course of a given season, innumerable threats to the crops appear ... The impact of drought plus whatever combination of pests and diseases attacks the crop in a given year can often reduce the average harvest on her farm by perhaps 50–60%, to 1000 kilograms of produce. *At this level of productivity, the family is on the edge of survival.*" [italics added]

From this, several factors are evident. The elimination of current food losses can shift the family from the 'edge of survival' to at least relative food security. The gains from such a strategy are significant and are sufficient to be attractive to poor households, but those most in need of such technologies are least able to pay for them. Reliability and consistency of performance are as important as absolute yield improvements and thresholds. A single mother, hoping to harvest a tonne of rice on a hectare of depleted upland soil, can ill afford to lose 100 kg of her harvest to a crop pest or disease in a single season, even if her average yields over several years may potentially rise. Moreover, she has so many demands on her very limited resources of cash and labour that she needs to know, as far as it is possible, that any investment she makes in crop improvement will repay the labour or cash adequately.

The costs of many of the improved technologies needed by smallholders, despite ongoing efforts at market development, will remain high. Low-cash-cost technologies often have a substantial cost in terms of labour – which is also a scarce resource in many poor households. But an expensive input can be profitable if it is used efficiently. Profitability of input use depends heavily on making best use of the limited amounts that the typical smallholder is able to purchase. The advice given to many poor farmers for the use of essential inputs, such as fertiliser, actually serves actively to discourage their use because of inadequate incorporation of basic economic parameters into farmer recommendations (Blackie, 2005).

The importance of efficiency of input use is further emphasised by the fact that the poor need cheap food. Poverty alleviation and food security have to be arranged around low food prices. With low food prices, the poor can use their limited cash to invest in better housing, education and health care. With high food prices, they are further trapped in poverty, and the opportunities for livelihood diversification are few.

## QUALITY AND IMPACT

The focus in the Green Evolution is on quality and impact, facilitated through enhanced networking and coordination among the various sector stakeholders and international organisations involved. Developing effective programmes that support commercialisation and market orientation, as well as poverty alleviation, needs a significant and sustained change in the way researchers go about their business. Green Evolution requires the mobilisation of a wide range of partners to contribute to the task of delivering the broader and deeper agricultural research and outreach agenda envisaged. Researchers need to move towards seeing themselves as participating directly in development, and to building the partnerships and networks that enable them to fulfil this expanded 'business-unusual' mandate.

The constraint on this transformation is not just management – it is leadership and vision. Three key elements underlie the strategy:

- a reformed and consistent research and outreach funding mechanism
- complementary human resource development activity that encourages quality, and a strong development and farmer orientation in all research and outreach activities
- adequate and high-quality physical infrastructure to undertake the detailed investigative and analytical work underpinning the necessary science, for example laboratories and the needed equipment, field facilities, irrigation systems, farm machinery and field transport.

Such a transformation does not just involve a change in management – it also needs leadership and vision from within the scientific community. The Asian Green Revolution led to the creation of the system of international agricultural research centres (IARCs), which plays such a major role in development science today. The fundamental hypothesis then was that, by assembling the best expertise in an area and providing good, consistent funding, rapid progress could be made in addressing tough technical problems. The model has worked, albeit with evident problems and limitations. An obvious area of weakness is the link between researchers and policy-makers. Typically, researchers are told that they need to influence policy, but there has been no similar pressure on policy-makers to listen to and incorporate the findings and opinions of researchers.

Sometimes researchers are able to influence the agenda, as the Crop Protection Programme (CPP) found with developing legislation for the registration of biopesticides in Kenya. Unfortunately, in most cases potential is unfulfilled as a consequence of this research–policy divide. This leads to research without support for its broader promotion and the implementation of suboptimal policies.

The UK's Department for International Development (DFID) CPP has focused considerable effort on enhanced networking and coordination among the national agricultural research systems (NARS) institutions, and with sector stakeholders and international organisations, through a policy of research and outreach funds being linked clearly and effectively to the quality of outputs – *funds follow quality*. The partnership focus requires that all partners play a proper role and that the development process involves enhancing the capacity of the weaker partners while moving efficiently to create solutions to the problems of poverty. This publication highlights some remarkable results that have come about as a consequence. This experience needs to be captured and developed.

At the core of the Green Evolution strategy, therefore, is a substantial and influential source of funding for research and outreach activities that works under radically different rules from those of the past. Those rules need to be developed and improved using the best of local experience (e.g. Banda *et al*., 2005). This creates a framework for a decentralised, farmer-focused research and outreach effort that has the capacity to deal with 'over-the-horizon' as well as immediate needs. The emphasis has to be, from the outset, on inclusion and openness – making the best use of talent and resources for the benefit of improving the livelihoods of all in poor rural communities.

## A NETWORKING MODEL

Researchers need to reach beyond the boundaries of their own disciplines and to start to engage directly with the poor. As the project summaries presented here indicate, much has been achieved in this direction but more is needed. In particular, from the outset, researchers need to understand the dimensions of poverty. Researchers need to be innovative and active further initiatives. Researchers have determined strategic themes from consultative stakeholders' meetings and then proceeded to implement programmes around such themes. These programmes are peer-reviewed (by key stakeholders including farmer groups and policy-makers, as well as scientists). The best options can be pulled together and then promoted through large-scale initiatives. The poor influence the choice of recommendations,

*The market place is an ideal networking model*

in developing partnerships and networks that can carry the best of their outputs quickly and efficiently into the hands of the poor. The need for better forward and backward links between research and policy has been stated many times, but suggestions as to how this could be done at a practical level have been limited, especially as many non-research-oriented development experts do not feel they have the time to explore research findings in any depth.

There are valuable opportunities to capitalise on the potential within existing research programmes. Agricultural research is often falsely perceived as being 'ivory tower'. *Perspectives on Pests II* showcases the talent field researchers have shown in creating teams that have gone on, not just to achieve project goals, but also to develop links and capacity that facilitate while the private sector contributes towards sector needs such as seed and market systems.

This networking model offers enhanced opportunities for providing the mechanism whereby research can influence policy. Planners can learn to understand the potential research has to offer, while researchers discover how to present data in a manner that is accessible to policy-makers. The outcome is a planned and intelligent approach to balancing the requirement for technical and social science components in the policy. This balance is the key to an efficient allocation of resources that will lead to poverty eradication.

The promotion of proven and well validated research, using proven and novel (but justified) communication pathways, can have a rapid impact on poverty. Existing projects, which have known technical and social strengths, can efficiently add value to a carefully focused development initiative. The evidence for this optimism comes from the experiences of successful and innovative projects like those presented in *Perspectives on Pests II*. They have served to strengthen farmer–extension–researcher–policy links for more coherent research and development policy. The objective is to create multi-agency, multidisciplinary buy-in, and to build teams that work systematically and with strong national leadership, to develop solutions to pressing national problems. This model encourages a coordinated, cost-effective and efficient technology-transfer process, using the best of national and international expertise in a focused, problem-solving effort. Local knowledge and expertise, both at farmer and researcher/policy-maker level, can be tapped to link research, extension and national policy to improve living standards for rural people reliant on agriculture.

## IMPLEMENTING THE DREAM

Significant benefits to the livelihoods of poor farmers can be created through the explicit incorporation of research outputs into development projects, programmes and policies. This is achieved through skilful networking of the best available talent – national and international – in a focused, problem-oriented mode to integrate high-quality technology into the development process. The success stories outlined in this publication show that, with strong leadership – especially from the research community – together with supportive guiding policies, the potential for research outputs from the natural and social sciences to address pervasive poverty can be released.

The first step is to build the teams, engaging a broad range of individuals and institutions, to focus on addressing the central theme of rural development in poor countries – the alleviation of poverty and the development of sustainable livelihoods for the poor and excluded. Innovation requires close and effective collaboration between 'public good' research and the market.

*CPP research efforts enable farmers to boost their productivity and improve their livelihoods*

While increasing the demand-led component of the research agenda is important, this will not, on its own, act sufficiently quickly to lift the technologically disconnected rural poor out of poverty. Fruitful interaction between academia, government and industry, which has led to the technology explosion in the wealthy parts of the globe, is needed to produce a strong and effective partnership between national and international science, and between science and the users of science – typically resource-poor smallholders.

Three central components can be identified, as follows.

- Intensive interaction with farmers – farmers are remarkably skilled at exploiting environmental niches on their own farms. This knowledge and skills base needs to be developed, conserved and promoted.
- Strong national-level technology development and dissemination capacity – indigenous knowledge is an active and dynamic concept. It draws on expertise and information from within and beyond farming communities, but with consistent, long-term indigenous leadership and vision providing direction and guidance.
- Strong and effective links to international science – the role of research in creating answers to problems of a scale unprecedented in human history needs to be carefully and skilfully orchestrated, and will require an adventurous new collaboration between international assistance agencies, universities and scientific establishments in both developed and developing worlds, and the private sector at both local and international levels. The scale of the problems facing vulnerable agricultural ecologies, as exist in much of sub-Saharan Africa, will require long-term continuing external scientific and technical support, but in a highly collaborative and interactive mode.

## BUILDING FARMER–SCIENTIST PARTNERSHIPS

Pro-poor agricultural research needs to involve low-income farmers and consumers as active participants in setting priorities for, and in the implementation of, research. Led in southern and eastern Africa by efforts of Collinson in the 1970s and 1980s (Collinson, 1972), building on work by a number of others, particularly in Asia and Latin America, farming systems research was based around a farm management-oriented informal survey process supplemented by secondary data from key sources and informants. Variations on this theme have been developed that have a broader, less directly agricultural focus – such as rapid rural appraisal and participatory rural appraisal (e.g. Chambers, 1994). The scientist facilitates the development of ideas and helps define options, rather than entering with already identified solutions. The overall theme is that of encouraging participants to take control of the process of change, thus empowering them to become more active partners in development.

The key element in creating farmer involvement is building the trust and respect of the farmers. This requires a continuing exercise of discussing and coming to a consensus on options, obtaining routine and informed feedback on results, and exploring new avenues based on field experience. *Perspectives on Pests II* shows that researchers have been highly innovative in developing the necessary tools, although their application now needs to be much more widespread and routine.

The challenge of conducting participatory research with many clients over an extended geographical area, common in pest and natural resource management research, is considerable. Working intensely with many partners over a large area would require huge financial and human resource investment and sound management to be truly effective. The CPP has effectively implemented a variety of cost- and time-effective research and research promotion strategies that depend on researchers working in collaboration with farmers.

### Mother-and-baby trials

CPP scientists have been early adopters of the 'mother-and-baby' trial design[1] developed by Snapp *et al.* (2003). The design comprises 'mother' trials that test a number of different technologies, and 'baby' trials that test a subset of three (or fewer) technologies, plus one control. The design makes it possible to collect quantitative data from mother trials managed by researchers, and systematically to cross-check them with baby trials that are managed by farmers. The design is very flexible – mother trials can be located on-farm at central locations in villages but, depending on need and logistics, they could as easily be located on nearby research stations. Farmer participation in baby trial design and implementation can vary from consultative to collaborative. By facilitating hands-on experience for farmers, the clustered mother-and-baby trials provide a relatively rapid approach to developing 'best-bet' options. The linked trial approach provides researchers with tools for quantifying feedback from farmers, and helps generate new insights and priorities (Snapp *et al.*, 2003).

### Benchmark sites

The Uganda National Banana Research Programme (UNBRP), in collaboration with the International Institute of Tropical Agriculture and CPP (R7567, R7972, R8301, R8342, pages 1–10) and others, instituted an intensive programme of research into bananas in Uganda in the 1990s in response to a major decline in the productivity of this national staple. An important feature of this effort was the establishment of benchmark sites, with the aim of accelerating the uptake of promising improved technologies by concentrating activities in certain areas from which baseline data would be collected. This would facilitate the identification of successful approaches that could then be promoted to other areas. This compares with previous uncoordinated approaches, in which farmers are offered only a restricted number of options to improve their cropping. The problem was considerable, with yields falling to as low as 6 t/ha. The life of a banana plantation had fallen from around 50 years to five to 10 years due to various social, economic and biological factors. Pests and diseases, including wilts, leaf spots (especially Sigatoka), parasitic nematodes and weevils, have caused many farmers to abandon their crops. As part of its drive to reverse this decline, the UNBRP is actively promoting the use of new, improved cultivars and the principle of planting banana material that is free from pests and diseases on pest-free and disease-free land – the so-called benchmark sites. For example, in Luwero, 128 farmers have been given 'clean' planting material of traditional East African cooking and brewing varieties, and new hybrid varieties, bred especially for their resistance to diseases. Farmers are also adopting recommended management practices of mulching and manuring.

The outcome has been a marked enthusiasm among the farmers of Luwero to return to growing bananas. Neighbouring farmers are also becoming interested in adopting the improved practices and re-entering banana production. The Banana Programme cannot produce enough of the resistant cultivar FHIA 17 (renamed Kabana 3) – even though the new cultivars do not have the same *matooke* or cooking quality as the true East African Highland cultivars and their bunches do not make the same price on the market.

## SCALING UP: BUILDING PARTNERSHIPS WITH THE WIDER COMMUNITY

### Creating change in potato systems in Bolivia

In Bolivia, CPP and partner agencies have supported a significant range of research projects into potato-based farming systems on hillsides in the mid-Andean valleys. These projects were commissioned and implemented to address a range of biotic and abiotic constraints facing poor producers. The national agricultural research programme is experiencing considerable change. As in many developing countries (Uganda is the prime African example), the Government of Bolivia is developing a new framework for agricultural research and extension (El Sistema Boliviano de Tecnologia Agropecuaria, SIBTA). Within SIBTA, four Foundations (FDTAs) have been established,

1. The terminology is, in fact, the farmers', who were delighted to have responsibility for their own trials.

one for each of the principal agroecological zones (Chacos, Altiplano, Valleys and Humid Tropics). The FDTAs are responsible for resource capture, research prioritisation, and the management of competitive grant schemes (using national and donor funds) for agricultural research and extension.

CPP has been highly active in promoting a collaborative effort on the promotion of improved potato technologies using the new SIBTA framework, and in engaging potential and existing partners (R8182, page 184). The aim has been to develop an initiative (INNOVA) directed towards achieving impact and maximising investments made to date, by validating and promoting outputs of past and present work. The FDTA Altiplano, currently the only SIBTA foundation with an interest in potato, has been fully involved in the initiative. The outcome has been an innovative, imaginative and impressive exercise that links demand with supply for agricultural research, while at the same time taking into account evolving market factors. The FDTA Altiplano strategy is strongly focused around improving competitiveness of the potato sector in the context of trade liberalisation under MERCOSUR. One of the activities in the plan is to identify demand for potato and other Andean crops, and to put out a call for research and dissemination activities. The potato food chain is complex, and the FDTA Altiplano requires technical support to identify products and associated chains with commercial potential, and to identify the demand for technical innovation along those chains.

## Farmer field schools

The farmer field school (FFS) approach has been widely adopted in Asia as a means of promoting integrated pest management (IPM). In Africa, the participatory learning approach has enabled participants to minimise pesticide use, enhance soil management and utilise weather surveillance to bring about improvements in crop health. More than two million rice farmers in Asia and South-East Asia have been trained in IPM FFS since 1989. Those farmers who have participated in FFS have managed to reduce their use of pesticides and improve their use of inputs such as water and fertiliser, realising enhanced yields and experiencing increased incomes. Alumni of FFS are now at the forefront of promoting sustainable agricultural systems in their communities. The underlying assumption is that farmers already have a wealth of experience and knowledge. The schools facilitate farmer-to-farmer knowledge sharing, provide practical, hands-on education that is highly participatory and linked to local issues and problems.

*INNOVA stakeholder platform brings together farmers, processors, entrepreneurs and researchers*

Farmer field schools have been used by CPP scientists in East Africa to disseminate integrated pest and production management (IPPM) strategies in sweet potato production (R8167, page 26) and horticultural production enterprises (R8299, page 128), and are an increasingly important component of the technology-dissemination process in West Africa as well. The CPP has been at the forefront of developing FFS for subsistence crops.

## Improving access to inputs

The CPP has been supporting work on a project (R8219, page79) implemented by Farm Input Promotions-Africa (FIPS-Africa) to scale up the promotion of 'mini-packs' of inputs such as seed and fertiliser in quantities farmers can afford, together with providing information on their use These are made available through Kenyan supply networks and promoted through various forms of farmer awareness activities. As farmers gain confidence in the profitability and use of new technologies, they return to their nearest stockist to purchase larger quantities (Blackie, 2005).

FIPS-Africa, a not-for-profit company, works with the private sector – Athi River Mining (ARM), Monsanto, Western Seed Company, Lachlan Agriculture and the Kenya Seed Company – and with public-sector agencies such as the Kenya Agricultural Research Institute. Their strategy enables farmers to evaluate a range of different technology options, including new seeds of maize, beans and vegetables; fertiliser types; and weed control options. FIPS has worked with ARM to develop an improved fertiliser blend, Mavuno, better suited to smallholder crops than the existing blends available in the market. FIPS has collaborated with Monsanto for both seed and conservation tillage technologies. Lachlan Agriculture (a Kenya-based agent for Dow Chemicals) also collaborates actively with FIPS on the use of SpinTor (spinosad) dust to control larger grain borer, a storage pest of maize. Currently available control technologies are unable adequately to halt the depredations of this devastating insect, which is capable of completely destroying the contents of a maize granary within three months of infestation.

FIPS collaborates with both private-sector firms and national research scientists in running FFS and demonstrations. It has a valuable role, acting as an 'honest broker' and helping farmers to choose and evaluate various technologies in an unbiased manner. It works through local stockists to ensure needed inputs are available for sale, and helps in the promotion of new options for farmers through a range of activities. These include collaboration with church and school groups, providing information at market days, and the provision of samples for farmers to experiment with on their own farms.

Evaluation data on FIPS show the approach to be remarkably successful in improving food security among participating farmers. Once their food crop is secure, they quickly start to use very small quantities of fertiliser on high-value cash crops such as kale and cabbage to generate income. Income growth and livelihood diversification follow rapidly. Using the Bass model (Bass, 1969) to predict future uptake pathways suggests there will be a steady increase in adoption, reaching 84% of farmers (some 300,000 new adopters of improved technologies) in the three districts currently served by 2011. This provides a reliable exit strategy for FIPS, which can then move to another site (either within Kenya or in a neighbouring country).

## Bringing in the human element

Impact and sustainability of change require ownership by the poor. Making farmers proud of their involvement, and making the adoption of change an enjoyable and interesting experience, is typically (often unintentionally) downplayed in many development programmes.

> *"Why if villagers can rapidly communicate important news about a death or birth to neighbouring villages, does it still take years for good seed varieties to spread from one village to another?"*
> Dr Ulicky, District Agriculture and Livestock Development Officer, Hai District, Tanzania

Repeated reinforcement of the need for a pro-poor focus by the CPP management – and the awareness and understanding of research teams – have led to the development of respect throughout project stakeholders. Therefore, in addition to the expected technical innovations, farmer empowerment, innovative communication strategies and increased links with other initiatives have been manifest. These will leave a legacy of strengthened farmer–extension–researcher–policy-maker–farmer links for more coherent research and development policy. The outputs from these projects could be quickly and easily incorporated into overall development policies with swift benefits for the poor (see Blackie and Mann, 2005 for an example of such an innovation in Malawi).

The CPP's experience is that the poor cannot afford to take chances and need reliable and trusted sources of information on new options as these become available. Again, the experience of the CPP has a lot to offer. A radio soap opera in Kenya, *Tembea na majira*, incorporating development issues, has an audience of nine million with impressive percentages of people taking on board the development messages included. In Tanzania the CPP is co-funding a radio soap opera, *Pilika pilika.* Analysis showed that the audience has been building even more quickly than in Kenya, and indicated that listeners wanted to know how to manage pest outbreaks on the important bean crop. Storylines involving improved bean pest management were woven into the radio programme (with assistance from Tanzanian researchers). The soap opera has only just begun, and already researchers have been unable to meet the demand for new varieties of beans.

Other CPP projects in Africa have successfully explored and developed community seed-multiplication systems for kale, *sukuma wiki* (R8312, page 118), potatoes (R8104, page 107), groundnut (R7445 and R8105, pages 57–60) and sweet potato (R8040, page 23). The sweet potatoes and groundnuts promoted were developed through research institutes that were unable, by themselves, to establish successful seed-production systems. Seed systems have also been developed for the sale of pigeonpea (R8205, page 149) and crotalaria (R8194, page 64) for *Striga* control in systems in southern Tanzania. Quality control was fundamental in all projects. For example, with the potato-multiplication project in Uganda (R8104, page 107), the Kapchorwa Seed Potato Production Association established local disease thresholds and a quality control committee conducts regular joint field inspections. As a result, the devastating disease of bacterial wilt has been reduced to below 1%. In just two years (to 2003), 36,000 farmers in Central Uganda tripled sweet potato production: 34,000 tonnes of improved sweet potato worth over US$2 million were produced during the project (R8040, page 23). Consumers also benefited from the enhanced vitamin A content of the tubers.

Researchers have worked as a team with farmers and have explicitly recognised the importance and potential of indigenous knowledge and farmer experimentation for both innovation and promotion (R7965, page 39). However, this potential is rarely fully exploited. Often, in Africa, social analyses will show the importance the poor attach to farmer-to-farmer dissemination of knowledge, but this pathway is rarely well exploited.

The project leader developed excellent social interactions with farmer groups in Tanzania, Kenya and Malawi, and facilitated knowledge flow in such a fashion that farmers felt that they had actually developed the solutions themselves. Once these solutions were seen to be a success, the project facilitated visits and meetings during which information was shared. The presence of natural scientists gave the groups credibility, and social scientists were able to ensure indigenous pathways were utilised. Farmers have become very proud of the project – over 70,000 have formed farmer groups that worked directly with the project and consequently are boosting their bean productivity. Of possibly greater importance, though, have been the spin-off benefits. The innovative project has led to farmers and rural dwellers (men and women) establishing innovation systems to address many other issues (Hall *et al.*, 2004). These have included digging a home water well, acquiring dairy cows (and developing a market for the produce), quality seed and credit, adult and health education, water conservation, using clay stoves to reduce firewood needs, and purchasing animal draught and implements. Farmers have become empowered while addressing major constraints to crop production. Founder farmers are now involved in teaching new groups. Farmers are not just following research-generated best practices, rather they are adapting research information to develop the most beneficial approach/combination of technologies for their individual circumstances.

## THE WAY FORWARD

The Green Evolution strategy builds on the best that exists, encouraging local expertise and contributions at all levels, yet is well integrated into international science. Change can be fast and far-reaching, but costs are affordable. It will create the broad-based change and sense of ownership that are needed to break out of the poverty trap that ensnares so many of the poor and disadvantaged of the developing world. A strong voice from the South is built in throughout the endeavour.

There is much that natural and social science research can offer policy. Researchers and policy-makers need to start, actively and creatively, integrating their capabilities to bring a swift end to the suffering of the poor. The examples provided in this publication provide evidence that this is both achievable and effective. The leadership and vision to make it happen must come from the research community itself.

Projects funded through the CPP have played, and continue to play, a key role in the Green Evolution. Through the technical outputs generated, through their adoption by farmers, and by showing others what can be done, CPP-funded projects have empowered farmers and researchers to be proud of their knowledge and to improve their practices. Benefits from these projects will continue to accrue over the years and it is vital that this more evolutionary approach is given credit. There is no blueprint for this approach: Green Evolution evolves out of the resources available, the people leading the project, and those for whom the project is designed. This flexibility leads to projects suitable to local needs that maximise local potential, and is a hallmark of CPP projects.

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# Integrated management of banana weevil in Uganda

**R7972**

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This project aimed to validate and assess the use of a biological control agent, the fungus *Beauveria bassiana*, to control one of the most damaging banana pests, banana weevil, within an integrated crop management system. The project has demonstrated that a locally discovered isolate of *B. bassiana* can be mass produced on a grain substrate. When applied in banana plantations the fungus will persist for three months, but activity is influenced by environmental conditions in the plantation. Applying organic material to the crop (an established recommended practice) limits persistence of the biocontrol agent. Efficacy in killing adult weevils can be improved by using aggregation pheromones and kairomones. Farmers have participated in trials and would be prepared to use this technology if the cost compares favourably with chemical controls.

## ISSUES

The banana weevil (*Cosmopolites sordidus*) is probably the most important arthropod pest of bananas, at least in Africa, and has long been considered a major constraint to banana production in Uganda. In the past, several control options have been considered, including the introduction of predators and the use of insecticides. However, predators failed to establish, and resistance soon developed where insecticides were used. Since 1991 UNBRP, in collaboration with its partners IITA, CABI ARC and the University of Reading, has been implementing an IPM approach to managing this pest.

This project focused on the potential for using the entomopathogenic fungus *Beauveria bassiana* as a major component of an IPM strategy. Various strains of the fungus had previously been isolated from soil and insect hosts in Uganda, and can cause 50–100% mortality in two weeks. Some isolates of *B. bassiana* have shown good growth and spore production on substrates locally available in Uganda, such as cracked maize and maize bran.

Previous field evaluations of delivery systems for *B. bassiana* have shown that applications of the entomopathogenic fungus with planting material, pseudostem traps or to soil around banana plants can be used to infect banana weevil in the field. This project investigated how application of *B. bassiana* can best be enhanced within the specific banana farming systems of Uganda.

*Banana weevils infected (top, left) and uninfected (below, right) by* B. bassiana

## ACHIEVEMENTS

In 2001 the project initiated studies at Kawanda, Uganda and CABI ARC, Kenya to evaluate the use of waste products and other locally available carbohydrate sources for mass production of *B. bassiana*. The mass-produced and formulated local isolate of *B. bassiana* was found to be highly infective to banana weevil in on-station experiments, and was further evaluated through farmer participatory trials. The epidemiological potential and persistence of the fungus under

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different banana management conditions were investigated at Kawanda by evaluating the performance of *B. bassiana* applied in fields with different organic and inorganic amendments, and also under different banana planting densities. Students attached to the project undertook specific research on the influence of soil organic amendments used in the banana farming system on the efficacy and persistence of *B. bassiana*; and the development of kairomones and pheromones in delivery systems for *B. bassiana*. [Unlike pheromones, which are attractant chemicals produced by the target species, kairomones are chemicals emitted by one species (in this case pounded banana tissues) that attract another species (the weevil).] In addition to these studies, an on-station field trial to evaluate the efficacy and persistence of *B. bassiana* applied under three plant spacings was established at Kawanda.

Results showed that *B. bassiana* can be produced in useful quantities on cracked maize and rice. The spore yields on these grains are superior to those from substrates based on waste organic products such as brewery waste and sugarcane bagasse. Over 1000 kg of maize was formulated with fungus for trials at Masaka and Kawanda, validating the methodology for small-scale production, but a full economic analysis is still required. A South African company has shown interest in producing the fungus commercially.

*Weevil damage in banana pseudostem*

The persistence of field-applied spore product was found to decline over time, the rate of decline being affected by environmental conditions in the plantation. Perversely, application of organic mulch that improves plant vigour and crop longevity, and closer plant spacing, were both found to increase humidity in the plantation micro-environment, which (although favouring plant productivity) hastens deterioration of *B. bassiana*. Two species of fungi, *Aspergillus flavus* and *Penicillium crysogenum*, are implicated in this. The results of field evaluations of persistence suggest that the fungus will need to be applied three or four times a year.

B. bassiana *delivery by semiochemical-enhanced traps in the field: top, kairomones (left, covered, right exposed); below, split pseudostem (left) and pheromone (right)*

Use of *B. bassiana* was tested in the field under different planting densities. After two crops, it appears that greatest weevil damage will occur at the closer spacing. Plant spacings of 2 × 2 or 2.5 × 2.5 m gave a higher yield per unit area than the currently recommended (conventional) spacing of 3 × 3 m.

Application of pheromones and kairomones (as pounded stem tissue) to pseudostem traps caused greater numbers of adult weevils to aggregate and be exposed to *B. bassiana* placed on the traps. Infection of adult weevils in the field can thus be improved by attracting weevils to baited traps. Infected weevils tended to stay around the banana mat on which they were infected, and transmission of infection to uninfected weevils was low.

Farmers participated in trials using *B. bassiana*, and have been made aware of its mode of action. A survey showed that, if commercialised, farmers would be willing to pay between US$0.25 and 1.25 per kg *B. bassiana* formulation.

The project also made effective use of students and has contributed directly to national capacity building.

## FURTHER APPLICATION

This project has tackled one of the most important arthropod pests of bananas, at least in Africa, and has shown that technologies are acceptable to smallholders and potentially transferable to them. On-station and on-farm activities are continuing through the promotion project R8482. The national agricultural research systems have a strong base on which to build promotional activities and the likelihood of uptake by beneficiaries looks good, provided other threats to banana production can be averted. Discussions are continuing with companies interested in commercial producion of *B. bassiana* in Uganda.

# Integrated management of banana diseases in Uganda

**R7567**

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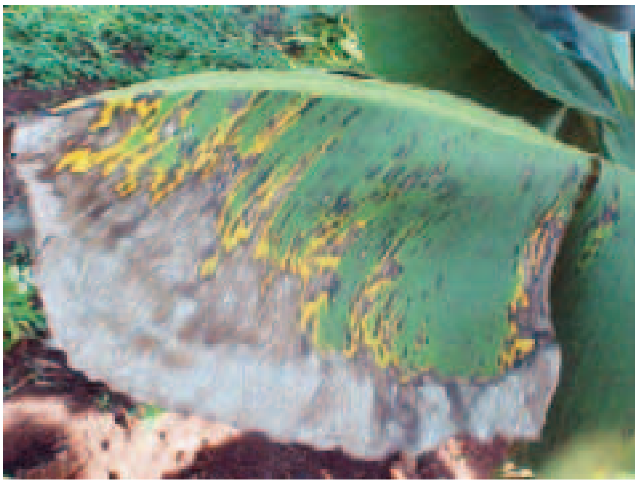
See R6794, R6006, R6007, R6692, R6391, R6579, *Perspectives on Pests 1996–2000*, pp. 31, 32, 72, 74

Yields of banana, the most important food crop in Uganda, have been steadily declining in recent decades, largely due to wilt diseases, leaf spots and parasitic nematodes. The Uganda National Banana Research Programme has previously identified cultural farming technologies with potential to reduce these problems and increase yields. This project was part of a multi-donor effort to assist the UNBRP in banana improvement. On-farm trials were carried out by farmers to evaluate and promote improved technologies, principally improved hybrids, indigenous highland banana types and the application of mulch/manure or fungicides. Clear beneficial effects were recorded with farmers, many of whom have formed growers' associations to pool resources and provide a forum for discussion, reporting increased yields and improved profits. In addition, investigation of a wilt-like disorder reinforced earlier findings suggesting that it is caused by nutritional problems related to farm management practices.

## ISSUES

In Uganda, banana is the most important single crop for food and income security. Annual production in Uganda is estimated at around 10 million tonnes, more than 15% of world output, most of which is consumed locally. The main cultivars grown are the endemic East African highland bananas, which have a high starch content and are used to prepare *matooke*, the staple food of Ugandans. Unfortunately these cultivars are limited in possibilities for utilisation, and are also susceptible to various pests and diseases including weevils, nematodes, and the diseases black leaf streak (*Mycosphaerella fijiensis*) and Sigatoka (*Mycosphaerella musicola*). Exotic cultivars are important locally, particularly as dessert bananas and for juice, beer and gin production. They are also in demand for export.

Over the past five decades there has been a steady decline in production of bananas in Uganda. While the area of land under bananas (about 1.5 million hectares) is double that in 1956, production in traditional banana-producing areas has declined severely, with annual yields falling from 20 to as low as 5 t/ha in the worst-hit East and Central Zone. Declining soil fertility, and a pest complex involving banana weevils, parasitic nematodes, fusarium wilt, leaf spots and banana streak virus have been identified as major constraints; post-harvest problems, socio-economic issues and low genetic diversity of the crop are also contributory factors.



*Leaf of banana cultivar Kisansa, grown in a non-mulched plot and devastated by leaf spot*

A programme was established by UNBRP in 1989 in an attempt to reverse this loss of productivity. Previous on-

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*A heavy bunch of Kabana 3 (left) is supported by props in a mulched plot, while local cultivar Kisansa (right) succumbs to leaf spot in a non-mulched plot*

station and on-farm evaluation revealed that a number of cultivars newly introduced to Uganda in 1995 are high yielding and also show resistance/tolerance to known pest and disease constraints (R6006, R6007, R6692). Further validation by relevant stakeholders was essential to reaffirm these attributes under more diverse and demanding environmental conditions, and utilising farmers' own selection criteria. To facilitate this work the UNBRP research programme identified three 'benchmark sites' representing different agro-ecological environments and reflecting three levels of banana production (severe decline; intermediate decline; high production). These benchmark sites have hosted a number of research and development initiatives funded by different donors, including this project.

From an economic point of view, investment in banana production is a long-term venture lasting between approximately 10 and 30 years, with economic returns usually becoming clear only five or more years after crop establishment. Nevertheless, a preliminary study was undertaken using the data acquired from the project trials to try and identify early economic benefits from the new varieties and cultural practices.

## ACHIEVEMENTS

The aim of the project was to build capacity and assist the UNBRP and Ugandan banana farmers to evaluate improved management technologies. The philosophy for the research was based on applying participatory approaches at all stages of the on-farm research and technology promotion programme. On-farm trials involved 128 farmers hosting evaluation/validation/promotion trials in 24 selected villages at the three benchmark sites. All farmers initially took part in sustained sensitisation and training in general farm management and pest management. Four of the farmers have been trained as trainers, and have subsequently trained 198 other farmers participating in various UNBRP trials.

The newly introduced cultivars have shown excellent levels of resistance to the leaf spot diseases – these newly bred cultivars also show a superior level of vigour in the field, which is reflected in significantly higher bunch weights than are produced by the local cultivars. They also appear more able to withstand the presence of nematodes, and possibly weevils. On-farm trials have shown that productivity is greatly enhanced (by 49–143%) if the plants are mulched – not only the new cultivars, but also the preferred and popular local East African highland types (see table). Although the studies on economic rates of return were limited in terms of the variables taken into consideration, findings of the trials suggested that applying nutrition through mulches is still a viable economic enterprise at one site for both the new cultivars and the East African highland types. Farmers reported that they were able to buy clothes for their families, pay school fees, improve on and build new homes and extend their areas of banana production as a result of the extra income generated through use of the new technologies.

Early impact of the technologies was very encouraging in terms of the excellent performance of cultivars being evaluated, the beneficial effects of manuring/mulching, and the positive feedback from farmers. This has

***"We have benefited in monetary terms through the sale of bananas, suckers, making local brew and gin (waragi). This has improved on our household income and we have been able to meet some of our household needs ... clothes, books for our children, radios, drums used in brewing gin, window shutters and house construction."***

Farmers' report on the promotion of exotic banana cultivars

***"Banana growing has helped us acquire friends. These include our customers whom we sell bananas to even at times on credit. They also lend us money when we are in need ... we have been able to form a farmers' group and are in the process of opening up an account in Wobulenzi bank"***

Farmers' report on control of leaf spots: Luwero benchmark site

| Weight (kg) of bunches produced by banana cultivars with and without mulch application in a technology promotion trial in Luwero District, Central Uganda | | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Cultivar | | | | | | Mean |
| | Kabana 1 | Kabana 3 | Kabana 4 | Kabana 5 | Kisansa | Mbwazirumee | |
| No mulch | 17.5 | 21.2 | 13.7 | 9.1 | 11.2 | 4.5 | 12.9 |
| Mulch | 26.2 | 33.5 | 33.3 | 13.6 | 18.7 | 16.4 | 23.6 |
| Difference | 8.6 c | 12.1 c | 19.6 c | 4.5NS | 7.5 b | 11.8 b | |
| Increase (%) | 50 | 58 | 143 | 49 | 67 | 264 | 83 |
| Mean | 21.9 | 27.2 | 23.5 | 11.3 | 15.0 | 10.5 | 18.2 |

NS, non-significant; a–c, difference significant at 5, 1 and 0.1% levels, respectively.
Significant difference between means (analysis of variance): treatment x cv = NS, Treatment = c, CV = c.

been confirmed by considerable demand for the hybrids tested and by a shift in production back to bananas from annual crops (cassava, maize, beans) in the trial areas. The research also provided a much better understanding of the performance of local and exotic cultivars under both existing and improved farm management practices. It has enabled farmers to experience and assess the attributes of the cultivars and management approaches, and of post-harvest products, at first hand, and to decide whether they would be appropriate and beneficial based on individual circumstances. Farmers, initially with the assistance of the project, actively and independently formed groups and clubs to provide a forum for discussion and decision-making, and to influence policy-makers to ensure the technologies are applied and promoted effectively.

Concern had been emerging over the development of wilt symptoms on bananas in southern and south-western Uganda (referred to locally as *matooke* wilt), and of the threat it may present to banana production if it is caused by a transmissible disease such as fusarium wilt. However, field observations, isolation of organisms from affected plants, soil/plant nutrient analyses and on-farm trials suggested that the wilt-like disorder is primarily caused by nutritional deficiency rather than a pathogenic organism, and highlighted the beneficial effects of composting and roguing in minimising the problem. (This does not refer to the banana bacterial wilt disease caused by *Xanthomonas campestris* pv. *musacearum*, first detected in Central Uganda in 2001.)

In addition to field trials, a broad range of activities was planned and undertaken throughout the project to help to promote the cultivars and management technologies concerned. These included agricultural exhibitions, farmers' open days, broadcasts on local, national and international television and radio, reports in local and national newspapers, production of videotapes, farmer competitions, and presentations at national and international meetings.

*Representatives of one of the groups formed by banana farmers. The UNBRP helped farmers to make notice boards which are displayed in villages across the sub-county*

## FURTHER APPLICATION

Planting material has been disseminated to a broad range of farmers who will continue the validation, promotion and, hopefully, onward dissemination process. This will be monitored through an applied follow-up project (R8342, see page 6), which seeks to expand the technology options available and to scale out and evaluate them.

The project has empowered farmers to make more informed and effective decisions on the technologies they use. Some of the methods tested received strong approval, were already being taken up by many thousands of farmers and may be adopted over the longer term, providing a sound basis for improved and sustainable banana production in Uganda for years to come. This is especially true and important in the East and Central Zone, where the recent decline in banana production has been dramatic, but where this project and other initiatives are helping to reverse the downward trend and revitalise production.

# Promotion of improved IPM practices for banana diseases and pests in Uganda

**R8342**

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July 2003–March 2005

Over seven million people in Uganda, including 70% of farmers, rely on banana as a staple food. But banana yields have been declining in recent decades. Using a participatory approach, stakeholders involved in banana production in Luwero, Mukono and Kayunga districts of Central Uganda, including farmers and representatives of extension services, NGOs, community-based organisations, the National Agricultural Advisory Service, local councils and national government, were presented with improved IPM options for banana production. The technologies, developed through a multi-donor effort at UNBRP benchmark sites, included the use of improved local and newly introduced improved banana cultivars with tolerance of or resistance to major pests and diseases. Based on the relative attributes of the management options, stakeholders identified and selected those cultivars that addressed their own needs. This project followed on directly from previous work (R7567).

## ISSUES

The banana crop, cultivated primarily by resource-poor, rural farming communities, is a major staple for seven million Ugandans. In terms of revenue, banana is the second most important cash crop after coffee, providing 22% of national agricultural revenue, and a vital source of income to acquire other foods, household necessities, children's education and medical care. Over the past 50 years there has been a significant decline in banana production in Uganda, as shown by a major shift in cultivation from the previously productive central region of the country to the south and south-west, where today productivity remains high.

Symptoms typical of banana bacterial wilt – uneven ripening of the fingers, drying and decay of the male bud and flower stalk (photo: Simon Eden-Green)

Many farmers in Central Uganda abandoned the banana crop after decades of cultivation to seek more lucrative activities, largely through migration to urban areas including nearby Kampala. Even in the south and south-west, where production of some banana types (such as beer bananas) is increasing, there has also been a general decline in crop productivity.

The programme established by the UNBRP to reverse this decline identified a number of IPM technologies to address a complex of recognised pest constraints, including nematodes, pathogens and insect pests (see R7567, page 3) and poor soil

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TUSHEMEREIRWE, W.K., KANGIRE, A., KUBIRIBA, J., NAKYANZA, M. and GOLD, C. (2004) Diseases threatening banana biodiversity in Uganda. *African Crop Science Journal* 12: 19–26.


*Mr Ubega Lubega, a Ugandan banana farmer, with his family. Adoption of the new banana varieties has provided the family with a reliable food source and increased income, enabling them to purchase some of life's essentials in Uganda – a cow, a bicycle and a mobile phone*

fertility. The technologies have been evaluated and, to some extent, promoted through previous CPP projects R7567; R7529 (banana streak virus); and R7972 (see page 10).

Banana streak virus is becoming an increasingly important constraint to banana production in Uganda. It has been suggested that its development is associated with very poor plant husbandry, a consequence of the high incidence of HIV/AIDS in the local human population drastically reducing the labour force able to tend banana stands. CPP project R7478 (led by the John Innes Centre) confirmed that banana streak virus is present throughout the banana-growing regions of Uganda. Transmission experiments completed for project R7529 indicated that a Ugandan strain of banana streak virus can be transmitted by mealybugs (*Planococcus* and *Dysmicoccus* spp.).

In the early stages of this project, the rapid spread and damaging effects of banana bacterial wilt (caused by the bacterium *Xanthomonas campestris* pv. *musacearum*) were also becoming evident in Central Uganda, especially in Mukono and Kayunga districts. The extent of the threat presented by banana bacterial wilt compelled the UNBRP and other national agricultural research and extension services in Uganda to give the disease high priority and to reallocate resources to counteract its growing impact. The objectives and activities of project R8342 were also realigned accordingly.

## ACHIEVEMENTS

The primary objective of this project was to take IPM technologies forward for promotion and dissemination to a broader range of farmers and associated stakeholders across a much wider geographical area than to date. The technologies include local and introduced, improved cultivars with resistance or tolerance to the major pests and diseases.

Through a participatory approach, a broad range of banana stakeholders, including farmers and representatives of extension services, NGOs, community-based organisations, the National Agricultural Advisory Service (NAADS), local councils and national government were presented, by the UNBRP, with improved IPM options for banana production in Luwero, Mukuno and Kayunga districts of Central Uganda.

Based on the relative attributes of the management options, stakeholder communities identified and selected those considered appropriate to their needs. Stakeholders were also identified who were capable and willing to act as intermediaries, or service providers, to communicate knowledge relating to the management options to local communities, thereby promoting their uptake, utilisation and ultimate adoption.

Participatory development communication, rather than a top-down approach, was employed to help ensure the success of various activities. In each district the project worked through pilot or model sub-counties, parishes and villages within which strong links and partnerships were developed, and where activities were, and continue to be, coordinated and supervised by community task forces established during the project. In these areas and beyond, considerable success has already been achieved in promoting management approaches that are now being applied to the benefit of farmers and their associates. Given limited resources, the intention was that the model communities would act as a catalyst for more widespread promotion and adoption of improved management practices.

While the project continued to address and promote IPM generally, steps were taken to incorporate and emphasise the problems associated with banana bacterial wilt by raising awareness of the disease and promoting management practices considered to be appropriate, such as removal of the male bud as a key infection point.

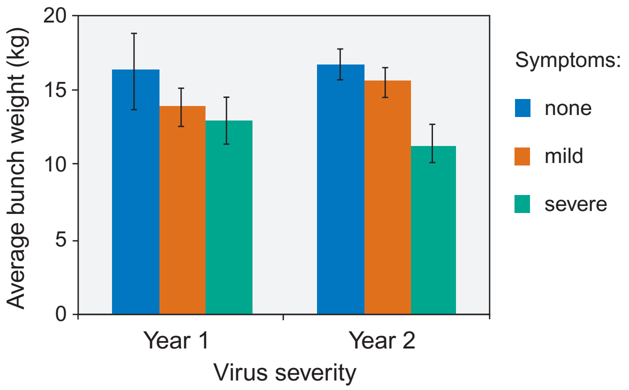
In-depth research on transmission of banana streak virus confirmed that at least three Ugandan mealybug species are capable of transmitting the virus between banana plants and that patterns of disease spread in the field are consistent with mealybug transmission, suggesting that mealybugs do need to be controlled. In terms of managing banana streak virus, removal of senescing and dead leaves (de-trashing) by farmers reduced mealybug populations and, while banana streak virus had a negative effect on plant growth, yield reductions (bunch weight losses as high as 32%) could be counteracted by more intensive management, including soil and water conservation measures such as mulching and manuring (see graphs). These findings are significant, and form part of the IPM promotional messages being conveyed to growers and other stakeholders.

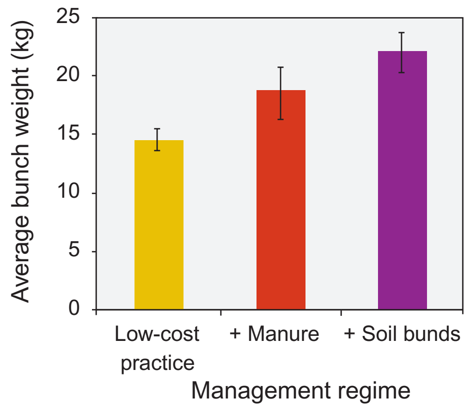
The project has been successful in employing a participatory approach to facilitate and nurture multi-partner communication and promotion of IPM practices with the key decisions being made, and demand expressed, by banana growers themselves as the ultimate beneficiaries. In the communities in which the project has operated, communication pathways are now in place. With the aid of communication materials developed as part of the project, farming communities have been empowered to employ more appropriate IPM practices for banana production.

A fundamental component of this work was the use of local intermediaries to act as communication channels between farmers and the UNBRP. By empowering banana farmers to select improved management technologies, the project has helped to increase production, productivity, utilisation and consumption of bananas and banana products in Uganda, and ultimately to improve the livelihoods of rural communities. Feedback from communities suggests that the benefits of banana production are being realised more widely, and that the willingness of farmers to produce bananas not only for food but also as a commercial enterprise has increased. A continuation of this trend will help ensure that bananas can be produced in sufficient quantity and of a required standard, so that improvements in food security will be attained and the incomes and livelihoods of those involved in the banana commodity chain, particularly the rural poor and including consumers, will improve.

## FURTHER APPLICATION

The activities of this project have been almost wholly adaptive and, being largely field-based, have been responsive to emerging threats such as banana bacterial wilt. Continued progress, in terms of the impact of the project on pest and disease control, banana production and farming community livelihoods, will be monitored systematically through follow-on project R8482. This short project will specifically monitor and evaluate the success of the promotional activities undertaken to date in selected areas and environments by seeking stakeholders' views and perceptions of the communication approaches employed, and by assessing the extent to which recommended management practices are being successfully applied. A related study (R8437) will assess the impact of banana bacterial wilt disease on rural livelihoods.




*Left, effects on bunch weight of different levels of banana streak virus severity; right, bunch weights under three categories of cultural practices*

# Archiving data from IPM projects within the Uganda Banana Research Programme

**R8301**

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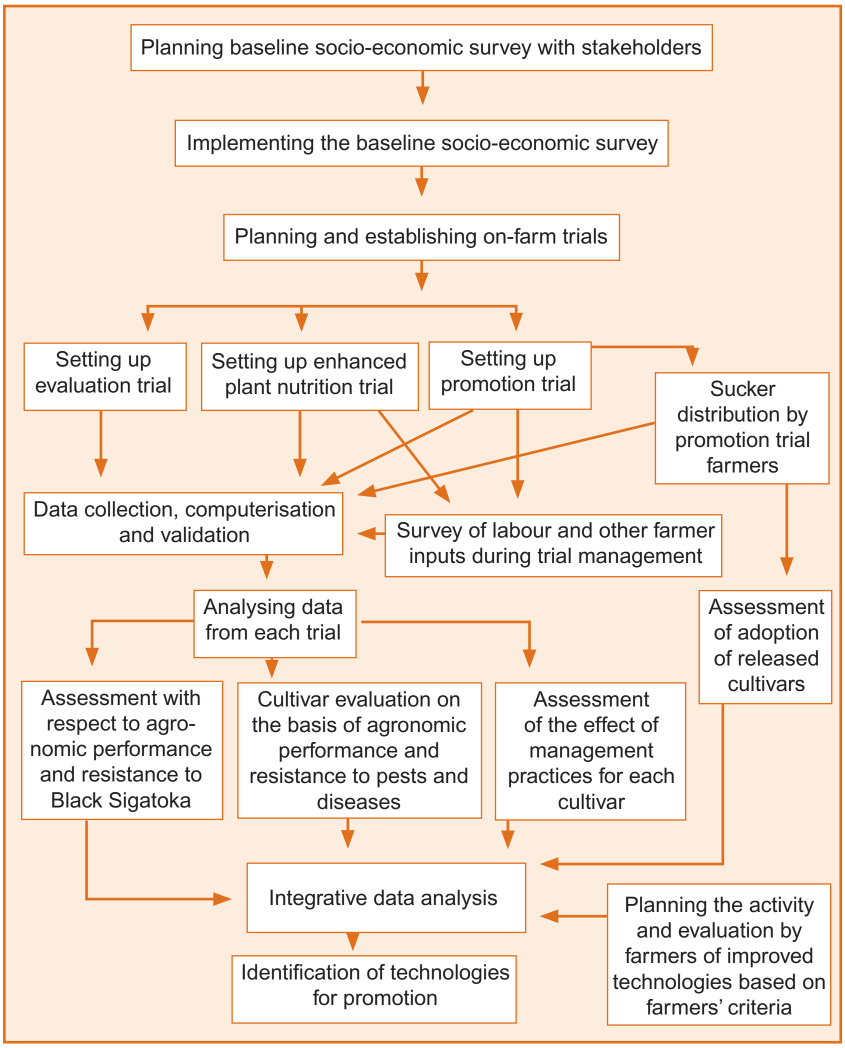
April 2003–May 2004

This project provided assistance to the UNBRP to help improve the quality of its research through a systematic approach to the collection, organisation and management of research data. Initial steps towards this goal were completed through the archiving of all data, meta-data, study protocols and other information obtained via three CPP banana projects; the establishment of guidelines and procedures necessary for maintaining a good data management system; and the development and documentation of an appropriate data management strategy for all UNBRP research activities.

## ISSUES

Data management has been a primary concern of the UNBRP for several years, following difficulties in producing results from a UNBRP Diagnostic Survey conducted in the late 1990s. There has been a substantial increase in the number of projects handled by UNBRP since then, but making comprehensive use of the data gathered from research has been compromised by the lack of an effective system for data management. The most interesting analyses in the future are likely to be those that integrate data from different




*Links between research activities for project R7567 (see page 3) as part of a project-level protocol*

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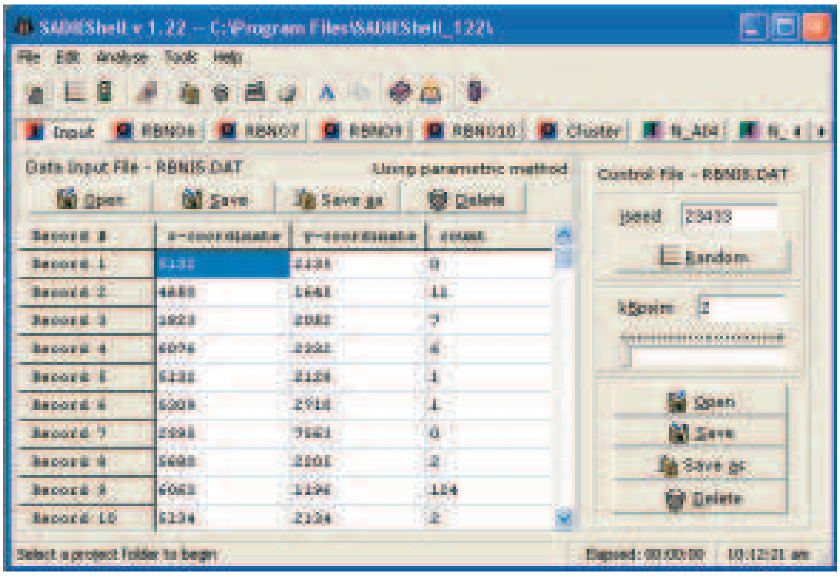
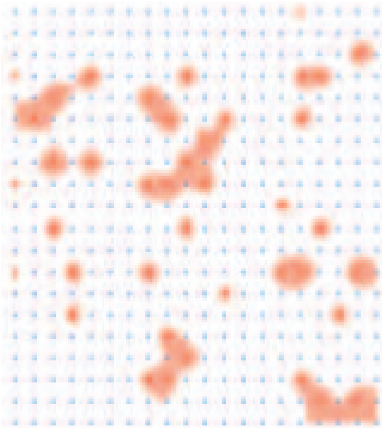
UNBRP (2004) *Uganda National Banana Research Programme Policy for Research Management with particular emphasis on Research Data Management and Statistical Analysis.* Uganda National Banana Research Programme, Kawanda Agricultural Research Institute, Kampala, Uganda, 14 pp. Available at www.banana.go.ug



*SADIE – free software used to measure and detect clustering (©Joe Perry, Rothamsted Research, Harpenden, UK) – was used to study the epidemiology of banana streak virus (R7529) by mapping the spatial spread of its mealybug vector in experimental plots. Top, spatial data after importing into the SADIE software; left, sample mapping results.*

component studies, and this will require high-quality data management and the availability of a properly maintained database management system.

The Research Support Unit of the World Agroforestry Centre (ICRAF) in Nairobi has developed a software tool called LOGBOOK to handle a wide range of study and data types. It was recognised that this tool would be invaluable in assisting UNBRP to develop a database management system, but a primary task before the commencement of such work was to assemble UNBRP data sets from a number of projects to establish the most appropriate direction for the database development work.

## ACHIEVEMENTS

Through this project, a cluster of CPP banana projects (R7567, page 3; R7972, page 1; and R7529 on the epidemiology, vector studies and control of banana streak virus in East African highland bananas) benefited from having a complete archive of all their research data, meta-data, study protocols (see flowchart on page 9) and other information set up in a centralised system within UNBRP.

The archiving work provided on-the-job training in writing protocols for UNBRP staff leading activities under the CPP cluster of projects, while a four-day 'Research data management' workshop gave 28 scientists, research assistants, technicians and data entry persons the opportunity to learn about procedures for minimising error at stages of data collection and computerisation, and appropriate methods for data management.

On-the-job training in further aspects of data management (e.g. see figure above) was also received by two members of staff from UNBRP's Biometrics Unit, consolidated through additional short-term training in the UK in research data management and statistics. This provided them with improved skills to give better support to other UNBRP staff.

In collaboration with UNBRP scientists, research assistants and technicians, a manual on *Guidelines and Procedures for Effective Data Management* was produced, and has been circulated to research scientists in the National Agricultural Research Organisation (NARO)'s nine agricultural institutes. Discussions with senior scientists of UNBRP led to the production of a *UNBRP Policy for Research Management with particular emphasis on Research Data Management and Statistical Analysis.* This has been accepted by UNBRP senior staff, and is expected to assist the programme management in monitoring banana research projects and related activities more effectively.

Research scientists, research assistants, technicians and data entry personnel in UNBRP are now well sensitised to the importance of paying attention to the quality of data and maintaining the meta-data alongside numerical data.

## FURTHER APPLICATION

Follow-up work is now progressing towards the development of a full database management system for UNBRP with assistance from a database expert from ICRAF, and support from the Statistical Services Centre at the University of Reading. This work is being funded by the Rockefeller Foundation as a direct result of initial work under project R8301.

However, the Director General of NARO has expressed the view that data management alone will not improve research quality without parallel improvement in research methods relating to appropriate study design and methods of data analysis, and discussions are ongoing to determine how these issues can be addressed.

# Evaluation and promotion of clean seed yam-production systems in Central Nigeria

**R8278**

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Danny Coyne, Biodun Claudius-Cole
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Steve Morse
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Str Nora McNamara, Moses Acholo
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January 2003–March 2005

See R5735, R6691, *Perspectives on Pests 1996–2000*, p. 8

Production of yams has been important to the survival and welfare of many generations of poor people in the tropics, and continues to make an important contribution to sustainable food security and income generation. In Nigeria, yams provide cash income for a wide range of smallholders, including many women who are very active in marketing tubers and yam products. A shortage of affordable, good quality, healthy yam planting material (seed yams) is a major constraint to increased production and productivity in much of West Africa. Good quality seed yams are expensive and often unavailable, and farmers perceive seed yam production as a risky business. Building on the work of previous projects, trial plots in farmers' fields and on-station assessed the suitability and effectiveness of potential seed yam production techniques. Results indicated that a simple system based on planting cut tuber pieces treated with a combination of a fungicide and insecticide could be a viable means for yam growers to produce their own clean seed yams. The economics of seed yam production need to be evaluated over several seasons, as after the initially expensive outlay on planting material there should be no need to buy more in subsequent years. The project has established a loose network of stakeholders in Nigeria with a strong interest in improving seed yam production, resulting in a call for the establishment of a seed yam growers' association in Nigeria.

## ISSUES

It is estimated that in south-eastern Nigeria, people in major food-producing rural areas consume 757 calories per capita per day from yams, compared with 354, 298, 185 and 149 calories from cassava, rice, wheat and grain legumes, respectively. Results from a recent food demand and consumption survey by IITA in three cities in northern Nigeria emphasise the continued high demand for yams, and also refute reports of the negative impact of urbanisation on the use of yams for food in Africa.

The yam's combination of dormancy and early drought tolerance allows flexibility in planting and harvesting periods as well as in use of labour. The traditional long fallows

*Yams on the way to market (photo: Danny Coyne)*

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*Seed yam seller at West Africa's largest yam market in Techiman, Ghana (photo: Danny Coyne, winner of 'Positive Developments: a photographic exhibition by NR International in association with The Eden Project')*

that characterised yam-based production systems in the past have become impossible owing to pressure on land from a growing human population. The most serious constraints to productivity are the high costs of planting material and labour, decreasing soil fertility, and increasing levels of field and storage pests and diseases associated with the increasing intensification of cultivation.

Yam planting materials are derived from the edible portion, the tuber, which is expensive (50% of production cost), bulky to transport, and has a low multiplication ratio (less than 1:10) in the field. The minisett technique for rapid multiplication of yam germplasm was developed by IITA and the Nigerian National Root Crops Research Institute. Minisetts are small pieces of tuber (25–50 g) which, if treated appropriately, can be planted at relatively high density and will produce small tubers (up to about 400 g) that are ideal to use as seed yams in the following season to establish a ware crop (projects R5735, R6691, R7504). However, this technology has not been promoted appropriately or adequately in target areas. Poor-quality planting materials tend to carry pests and diseases from the barn back to the field, resulting in adverse effects on field establishment, low tuber yields and consequent carry-over to the following season.

This project aimed to assess if the scarcity and expense of clean planting material was a major constraint to yam production. Work was carried out with farmers, through local partner organisations in Kogi and Ekiti states, to evaluate systems for the cost-effective, sustainable and environmentally sound production of clean planting material.

## ACHIEVEMENTS

A household baseline situation analysis in Igalaland (Kogi State) and Ekiti State in 2003 reconfirmed that most yam growers were purchasing their seed yams because they believed seed quality was important. However, the high cost of seed on the market was a limiting factor in increased yam production. Production of their own seed yams was considered a high-risk activity which most growers would not consider entering into unaided. A typical coping strategy, especially in Ekiti but also in Igalaland, was to use yam setts (pieces of tuber up to 500 g) in place of seed yams. Igala farmers were obtaining much of their seed yam material from areas further south on the River Niger (Illushi). Farmers in Ekwuloko (Kogi State) obtained some of their seed yam from illegal planting within protected forest reserves. In both

*Sale of seed yams (left) and inspecting yams in store (right)* cases the transportation costs were high. Credit emerged as a key constraint for the establishment of clean seed yam production, especially in Igalaland.

On-farm trials in 2003–04 and 2004–05 confirmed that planting tuber pieces of 100–150 g, pre-treated with a cocktail of a fungicide, insecticide/nematicide and wood ash, is an effective method of producing healthier seed yams. Pre-treatment of planting pieces with neem leaf slurry gave very variable results, while the results for a pre-planting hot-water treatment appeared to be variety-dependent. Additional experiments were established to assess the interaction between hot-water treatment and variety. Results from farmers' fields for the 2004 season indicated substantial improvement in yield, size and quality of seed tubers using the recommended pesticide mixture compared with farmers' normal practices.

A detailed household livelihood analysis, incorporating a cost–benefit study of home seed yam production on four farms in Ekwuloko and four farms in Ado-Ekiti in the 2004–05 season, generated much information. Early indications from the Ekwuloko case studies are that, while households are involved in a diverse range of income-generating activities that place demands on labour, home production of seed yams can be cost-effective in some situations. However, because there are so many calls on the farm finances there is rarely sufficient funding available at the right time, nor sufficient incentives for farmers to attempt to grow their own seed yams.

A series of yam pest and disease identification sheets and posters and a project promotional calendar were developed and distributed in the 2003–04 and 2005 seasons. A simple seed yam-production guide based on the project findings was also developed in response to an expressed need by project partners (growers and extension agents).

*Women are most active in marketing yams (photo: Susan Seal)*

A wide range of stakeholders (including yam growers, extension agents and other NGOs) have participated in planning meetings, hosted trial plots, visited demonstration plots and attended participatory farmer field days following the harvests of farmer trials. Demonstrations of the suggested method for seed yam production (resulting from the project findings) have been provided for farmers at state trade and agricultural fairs and NGO field days. An end-of-project workshop was held to assess the project outputs and achievements with some of these stakeholders, and to develop links and a network for promoting improved seed yam systems within Nigeria.

The project has confirmed that, in the study areas, yam production is a major contributor to sustaining livelihoods. Productivity will be improved if the supply of good quality seed yams can be increased. There are relatively simple systems available to growers for producing their own good quality seed yams, but these require financial investment by growers at times of the season when currently most do not have access to such funds.

Provision of credit for small-scale farmers has been an issue for many years in Nigeria, and sustainable large-scale solutions have been elusive (for example with the collapse in the 1990s of the state-sponsored 'People's Bank', modelled on the Grameen Bank of Bangladesh). Commercial banks have little interest in providing credit for small-scale farmers, given the risks and the relatively high transaction costs. While a targeted and sustainable micro-finance credit scheme would provide growers with funds at the appropriate time to allow them to start growing their own seed yams, a means of sustainable provision is required. Some NGOs in Nigeria do have long experience of such provision, and it would be possible to adapt the livelihoods approach to become a rights-based business plan which could become the basis of a partnership between NGO and farmer. The farmers would then become local suppliers of planting material, eliminating the high costs of transport from distant sites. By specialising in seed yam production it is more likely that farmers will be able to produce quality material, and these benefits should make seed yams more affordable.

## FURTHER APPLICATION

A follow-on project (R8416) aims to:

- identify components of commercial seed yam-production systems potentially applicable to the production of clean seed yams by small-scale growers
- assess sustainability of small-scale seed yam-production systems in the contrasting ecologies and livelihood systems of Alla-Olakudu/Makoja and Ekwuloko
- evaluate a micro-credit scheme (supported by the Irish charity Gorta) for seed yam production in Ekwuloko
- transfer seed yam production systems/technologies to promotional partners
- identify needs for other promotional materials.

# Participatory breeding of superior, mosaic disease-resistant cassava

**R8302**

**Joint-funded with Plant Sciences Research Programme**

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Joseph Manu-Aduening
*Crops Research Institute (CRI), Ghana*

April 2003–March 2005

See R6617, *Perspectives on Pests 1996–2000*, p. 10

Cassava is the cheapest starch staple available in Ghana. It is a particularly important food for both rural and urban poor, and a source of food security. The aim of this project was to improve Ghanaian farmers' access to cassava diversity, and to work with them to develop a range of superior, disease-resistant cassava clones appropriate to their needs. For the first time in Africa, a farmer-participatory approach to breeding cassava from the seedling stage was applied. Analysis of clones selected over three generations indicated that this approach enabled farmers and scientists to work together beneficially. Superior clones are selected quickly because validation by farmers, a cassava breeder, and plant pathologists is achieved simultaneously rather than sequentially. The clones selected need to be released officially if they are to benefit from wide dissemination through official means, and the additional trials needed to achieve this have been identified and planted. Surveys have identified the main characteristics of current cassava end-users in Ghana, and potential and expanding uses in non-traditional foods, livestock feed and non-food uses. A side effect of this has been to improve links between the conventional breeding process in Ghana and the end-users. Clones selected through participatory breeding are being trialled on farms owned by two medium-scale food processors, and flour derived from clones selected by the project has been characterised biochemically.

## ISSUES

Cassava is a significant part of the diet of many people in Africa, and contributes about 22% of Ghanaian agricultural gross domestic product. Its production in Ghana is increasing, replacing yam, cocoyam, plantains, grains and other crops. About 80% of the population rely on it as their main starch staple, providing 18% of dietary energy, more than any other crop. About half the production is consumed fresh in local products such as *fufu* (pounded into a thick paste), and the remainder is processed, for example into *gari* or *kokonte*, dried products that may be stored for long periods and are relatively easy to transport to distant markets.

Cassava also provides a significant source of income through both sales of the storage roots and providing employment in small processing units (e.g. for *gari*). A President's Special Initiative has recently launched a cassava-based starch-production industry, targeting mainly export markets. The Government of Ghana's recognition of the importance of this crop is also indicated by the Roots and Tuber Improvement Programme (funded by the International Fund for Agricultural Development and led by the Ministry of Food and Agriculture) which aims to enhance food security and increase the income of resource-poor farmers. One of the key elements in achieving this aim is increasing the availability of improved cassava planting materials.

*Farmers showing the high root yield of one of their selected clones*

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MANU-ADUENING, J.A., LAMBOLL, R.I., AMPONG MENSAH, G. *et al.* (2006) Development of superior cassava cultivars in Ghana by farmers and scientists: the process adopted, outcomes and contributions and changed roles of different stakeholders. *Euphytica* (in press).

A number of pests and diseases cause major problems on cassava, including cassava mosaic geminiviruses (CMGs). Although CMGs affect cassava crops throughout Africa, the disease has also been associated with national or regional epidemics flaring up every few decades. Such an epidemic is currently devastating cassava production in East and Central Africa, and is threatening West Africa. Previous work (R7565) in two communities in Ghana suggests that farmers know much about the symptoms and causes of insect pest damage and of the symptoms of various diseases, but have less understanding of what causes diseases, including cassava mosaic disease (CMD).

Breeding work in Africa on cassava has been primarily on-station, although generally with final validation on-farm. A selection derived from an interspecific cross with *Manihot glaziovii* (tropical *Manihot* species, TMS) became the basis for a series of agronomically improved CMD-resistant cassava clones and seed, which have provided the main control strategy in Africa for several decades. More recently, another source of resistance has been identified in some West African landraces, leading to the TME (tropical *M. esculenta*) series of clones.

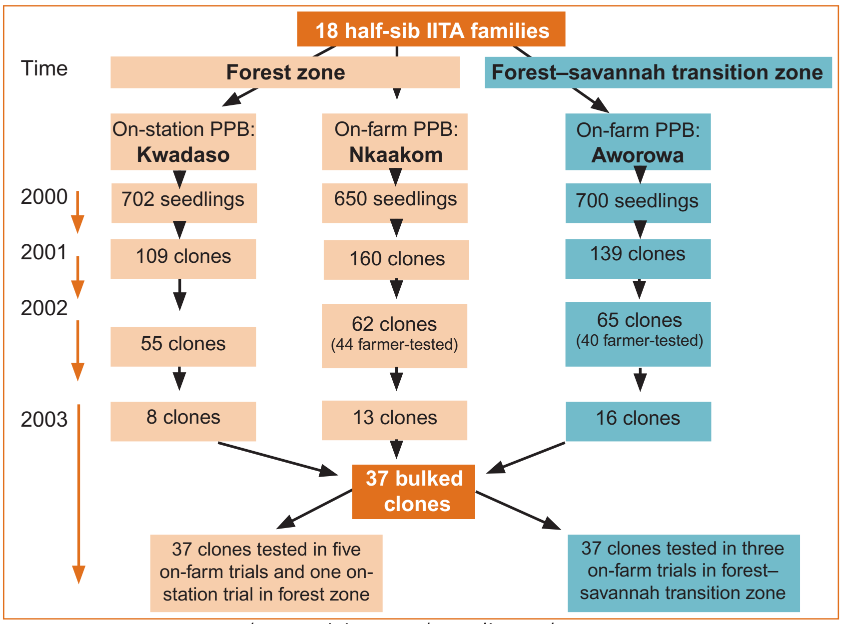
Only four varieties of cassava had been released in Ghana in the past few decades. A number of new varieties have now been released by the Savannah Agricultural Research Institute, Kwame Nkrumah University of Science and Technology, Kumasi and CRI, but it is too early to assess uptake by farmers. Landraces remain the main means of cassava production in Ghana, as in much of Africa.

## ACHIEVEMENTS

This project continued the development and validation (begun by R7565) of a process involving the participation of both farmers and scientists for selecting superior disease-, pest- and weed-resistant cassava clones. The aim was to select clones that are more adapted to local conditions and more appropriate to the needs of farmers and other end-users than those selected by the current on-station selection process. This is the first application in Africa of selection by both farmers and scientists from a wide diversity of cassava seedlings, provided by scientists and grown on-farm by farmers. Farmers, a formally trained cassava breeder and plant pathologists from CRI made separate selections over one seedling generation and three subsequent clonal generations, in which genotypes selected by any one of these three groups were retained (see figure). This process ensured the selections of each group were all retained, with no opportunity for one group to influence the others and coincidentally allowing opportunities to analyse the outcomes of selections by each group.

Participatory plant breeding activities in two communities and at an on-station trial, monitoring the characteristics of selected accessions through several generations, have led to the selection of 37 superior clones that are being tested in further multi-locational community trials in Brong Ahafo and Ashanti regions. The bases for the breeder's and the plant pathologists' choices were predetermined; the basis of the farmers' choices was determined by questionnaires at each harvest. The breeder placed most emphasis on yield; the plant pathologists on absence of foliar diseases; and the farmers on a diversity of storage root characteristics (of which high yield is the main one) and canopy formation.

Farmers, the CRI plant breeder and plant pathologists all tended to make broadly similar selections, as indicated by a considerable degree of overlap between their choices. Despite this, each group of selectors (particularly the farmers) made many unique selections, highlighting the value of their inclusion. Farmers' selections, in particular, were also reasonably consistent from one generation to the next, demonstrating their competence in selection. The project capitalised on unique selections by different groups by ensuring that selections of all groups were retained from one generation to the next. This did not slow the elimination of inferior accessions excessively: the progress of selection of superior accessions occurred at a similar rate to that of conventional plant breeding and benefited from all groups selecting simultaneously, so there is no need for subsequent on-farm testing by farmers. The selection process has identified genotypes that




*The participatory breeding scheme*

*Clockwise from top right: pounding* fufu*, Suhum, Eastern Region; large-scale starch processing, bagging of high quality starch, Awutu-Bawjiase, Central Region; medium-scale multi-purpose processing, milling flour, near Amasaman, Greater Accra Region; small, family-run, peri-urban* gari *processor, Cape Coast, Central Region*

are high-yielding under farmers' conditions, and with a relatively high and well branched canopy intercepting a high percentage of light. The accessions selected appear moderately resistant to diseases, and are likely to shade out weeds. These results validate the participatory selection process adopted – all groups, particularly farmers, made their selections in an effective and individual, yet inclusive manner.

The method will not finally be validated until long-term adoption by farmers is demonstrated. This is being enabled in the communities in which the project works directly, by allowing farmers to take cuttings of their preferred accessions to plant on their own farms. Relying on farmer-to-farmer transfer of superior accessions is expected to be slow. The project is well placed within the official Ghanaian system to release superior genotypes through the Ghanaian Variety Release Committee, enabling official systems to distribute more widely. Analysis of previous release documents demonstrated the lack of a broad enough range of multi-locational trials in specified agro-ecologies, so additional multi-locational community trials have been planted in Brong Ahafo and Ashanti regions.

A weakness of the project's initial participatory approach (and of conventional cassava breeding at CRI) was a failure to address the needs of cassava end-users other than farmers. This has now been addressed by surveys of non-farmer end-users, current and potential uses of cassava, and the activities of post-harvest researchers in Ghana. The results of these surveys have led to an initial pair of trials of superior accessions selected by the project at farms of medium-scale manufacturers of cassava food products. The surveys were conducted either by, or in close cooperation with, the CRI plant breeder. This activity has achieved a closer working relationship of the CRI cassava breeder with non-farm end-users and scientists at the Food Research Institute in Ghana, resulting in starch characteristics being included in cassava variety release documents for the first time in Ghana (and perhaps in Africa).

This participatory breeding project has provided an approach by which farmers, a plant breeder and plant pathologists can work together in an effective and inclusive manner in selecting cassava genotypes from seed. It also provided an environment whereby farmers made a significant and consistent contribution to the outcome of selection.

## FURTHER APPLICATION

A project extension (R8405) aims to submit documentation of the requisite characteristics of selected cassava genotypes to the Ghanaian Variety Release Committee, and as a result to release one or more varieties in Ghana. This would achieve independent, official validation of the participatory breeding approach, and provide a 'worked example' of how to achieve it to other researchers.

The same participatory approach has been transferred to Uganda and Tanzania for selection of farmer-preferred and sweet potato virus disease-resistant varieties of sweet potato (R8243, page 28; extension project R8457). Because sweet potato has a much shorter generation time than cassava, this activity in Uganda has already reached a similar stage and appears to have quickly identified several high-yielding, disease-resistant clones, which farmers are also already multiplying and adopting. These clones also appear to be particularly well adapted to the marginal lands to which this crop is often relegated. Again, the material has been adopted by the national programmes for inclusion in multilocational trials, with the ultimate aim of national release.

# Maximising and promoting the benefits to farmers of cassava mosaic disease-resistant varieties

**R8303**

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April 2003–March 2005

See R6765, R6614, *Perspectives on Pests 1996–2000*, pp. 13–17

Cassava is among the most important food crops for the rural poor throughout Africa, both for food and food security. A pandemic of cassava mosaic disease (CMD) associated with very large populations of their whitefly vectors has been devastating the crop in East and Central Africa. This project validated control methods (CMD-resistant varieties; selecting disease-resistant planting material; intercropping with a resistant cassava variety to protect a susceptible one) and means of disseminating knowledge of them to farmers in East Africa. This work has also shown that whiteflies are now a direct pest of cassava in Africa, as well as the vector of its main disease. Major progress has been made towards their control: previously unknown sources of whitefly resistance have been identified not only in African landraces, but also in advanced breeding lines sufficiently superior in yield and CMD resistance to be trialled for national release. If successful, this material will be a major weapon in the fight to control direct damage by whiteflies, and will contribute to protecting the crop against CMD and the spread and evolution of more whitefly-borne viruses.

## ISSUES

Cassava mosaic disease (CMD), the most damaging insect-borne disease of African food crops, is the main constraint to cassava production in Africa, diminishing production by an estimated 15–24% (12–23 million tonnes per year). CMD is caused by viruses belonging to the genus *Begomovirus*, family Geminiviridae. Cassava mosaic geminiviruses are transmitted in the persistent manner by the whitefly *Bemisia tabaci*. The disease is caused mainly by two viruses – African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV). Previous projects (R6614, R6765, R7565) have shown that the spread of CMD in East Africa from the late 1980s was associated with unusually large whitefly populations, rapid spread of CMD and very severe disease symptoms. The cause is now known to be a natural recombinant of ACMV and EACMV. This new strain, called EACMV-Ug ('Ugandan variant'), alone or in dual infections with ACMV, was shown experimentally to cause the severe symptoms typical

*Severe CMD on a CMD-susceptible variety (foreground) contrasted with a resistant variety in the background*

## SELECTED PUBLICATIONS

COLVIN, J., OMONGO, C.A., MARUTHI, M.N., OTIM-NAPE, G.W. and THRESH, J.M. (2004) Dual begomovirus infections and high *Bemisia tabaci* populations: two factors that drive the spread of a cassava mosaic disease pandemic. *Plant Pathology* 53: 587–614.

COLVIN, J., CHOWDA REDDY, R.V., REKHA, A.R. *et al.* (2004) Ecological and reproductive isolation amongst African and Asian *Bemisia tabaci* populations. In: *2nd European Whitefly Symposium*, Cavtat, Croatia, 5–9 October 2004 (abstract).

LEGG, J.P., SSERUWAGI, P. and BROWN, J. (2004) *Bemisia* whiteflies cause physical damage and yield losses to cassava in Africa. p. 65. In: *6th International Scientific Meeting of the Cassava Biotechnology Network* (abstract).

OMONGO, C.A., COLVIN, J., SSERUBOMBWE, W. *et al.* (2004) Host plant resistance to African *Bemisia tabaci* in local landraces and improved cassava mosaic disease resistant genotypes in Uganda. p. 84. In: *6th International Scientific Meeting of the Cassava Biotechnology Network* (abstract).

*Farmers in Tanzania emerging from a sea of healthy, highly CMD-resistant cassava varieties (photo: James Legg)*

of the epidemic. Its arrival in Tanzania in 2000 has resulted in the Department of Research and Development giving highest priority to controlling virus diseases of root crops (principally CMD) in the Lake Zone. As in Uganda, the pandemic has already created much hardship in these newly affected areas to the west of Lake Victoria. The impact looks set to increase dramatically as severe CMD spreads to the south and east of the lake, where farming communities depend even more on cassava for their livelihoods.

Modern resistant varieties provide the main control strategy for the CMD pandemic in Africa, but no single variety is perfect. This project, in partnership with the international Tropical Whitefly IPM Project (R8041), aimed to validate modern resistant varieties and other control technologies, including selection of planting material and mixing susceptible landraces with resistant varieties, in a close working collaboration with farmers in Uganda and the Lake Zone of Tanzania.

## ACHIEVEMENTS

Working with farmer groups in Uganda and Tanzania, the project has tested the use of CMD-resistant varieties, selecting disease-free planting material and different cultural control practices, notably intercropping with a resistant cassava variety to protect a susceptible one. Field demonstration plots in five farmers' fields in Mukono have demonstrated to farmers (and validated for researchers) the lower incidence of CMD in resistant varieties (00067; TME14; TME204; NASE 10) and in carefully selected disease-free planting material of CMD-susceptible landraces planted among a CMD-resistant variety. The final incidences of CMD in the local varieties (Kabwa and Njule), when grown with a CMD-resistant variety (00067), were 45% for Kabwa and 73% for Njule, in Mukono District, versus 68 and 99% when grown alone. Comparable figures for two other locals (Bao and Nyaraboke) in Apac were 57 and 58%, respectively versus 73 and 83% when grown alone. In the mixed crops, healthy plants remaining at the end of these experiments were sufficient to provide clean cuttings for further plantings. Civil unrest in northern Uganda resulted in the abandonment of work in Lira and its late replacement with work in Soroti.

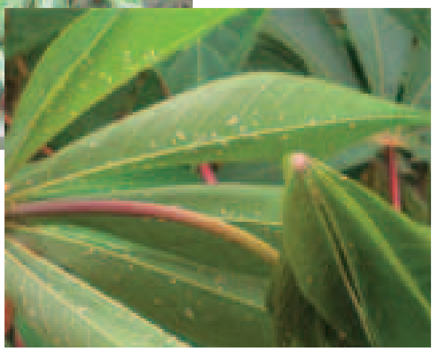
Resistance was clearly the most effective means of controlling CMD, but the cultural control measures did provide a means by which farmers were able to sustain production of moderately resistant local landraces despite the pandemic.

A leaflet describing the causes, means of spread and various ways of controlling CMD through the use of high-yielding resistant varieties has been produced by the Uganda team in English, Kiswahili and Luo. A guide in Kiswahili describing the causes, means of spread and ways of controlling both CMD and sweet potato virus disease (which, like CMD, is spread by whiteflies) has been drafted by the Tanzanian team. Members of the Tanzanian team have also visited Uganda to exchange ideas.

Training in how to control CMD has been provided to farmers in the collaborating farmer groups in Uganda. Here, however, the pandemic has long been established and most farmers are already aware of the causes of the disease. In Tanzania this is not the case, and the project has collaborated with other organisations, notably Norwegian People's Aid (NPA), to provide training for extensionists, mostly within the Lake Zone but also further afield in the country. This collaboration with NPA has also extended to providing technical aid in the dissemination of planting material of resistant varieties.

Populations of whiteflies one to two orders of magnitude greater than before the CMD pandemic have been observed, notably in Uganda but also in other countries affected by the pandemic. Sooty mould is often observed blackening middle and lower leaves where whitefly excreta have become infected with fungi. Chlorosis and stunting of middle and upper leaves occurs, caused on the upper leaves by adults feeding, and on middle leaves mainly by nymphs feeding.

A trial repeated in two seasons, and involving eight varieties differing in apparent susceptibility to whiteflies, was conducted in Uganda to assess the effect on yields of using insecticides to control whiteflies. The insecticides controlled the whiteflies, removing observable signs of whitefly feeding damage, reducing the spread of CMD in susceptible varieties, and generally leading to a higher root yield. The higher yield was seen in both CMD-susceptible and near-immune varieties, so it was not the result of reduced spread of CMD. These results also demonstrate for the first time in Africa how the spread of CMD can be decreased by the use of insecticides to control the vector.



*Above, whitefly damage (sooty mould) on cassava; right, whiteflies on underside of a cassava leaf*

Large numbers (279) of Ugandan landraces have been screened for resistance to whiteflies, leading to the identification of a few resistant ones, such as Njule. Some released varieties also appear to support relatively few whiteflies. Screening of advanced clonal accessions in national advanced and uniform yield trials has also identified potential resistance in these clones. In particular, the clones MM96/4271 and MM96/0686 supported few whiteflies and whitefly nymphs in uniform yield trials, and were also chosen by farmers and scientists using other criteria. Resistance of the identified clones has been confirmed in screenhouse preference tests. It is important that this work is continued so that future released varieties will be less susceptible to whiteflies than some previous releases.

Project scientists have also identified an outbreak of another whitefly-borne virus, cassava brown streak, in Uganda (see R8227, page 20). This seems likely to result from the large numbers of whiteflies affecting cassava crops in Uganda, and whitefly resistance may be a key component in its control.

## FURTHER APPLICATION

The sustainability of this approach needs to be tested, and there is also scope for trying intercrops or barrier crops. Such work should be done in different areas to cover a range of different circumstances and infection pressures.

The cassava mosaic pandemic continues to expand in and from the Lake Zone in Tanzania, with severe effects on the livelihoods of poor rural people there, many of whom are unusually dependent on cassava for food because the dry conditions limit the growth of other crops. It is also affecting many other Central African countries, including Rwanda, Burundi and the Democratic Republic of Congo, and appears to have the potential to spread throughout sub-Saharan Africa. This project plans to disseminate knowledge of and materials for the control of CMD; to train government and NGO extensionists using the protocols and materials developed; and to disseminate resistant materials.

Future work should address the problem of how to improve the current unsatisfactory health status of the many local varieties still being grown, some of which are highly regarded by farmers. A more farmer-participatory approach to cassava breeding (see R8302, page 14) could facilitate the development of resistant varieties with the preferred characteristics of these local varieties. Currently local varieties predominate in a high proportion of all plantings, yet they are almost totally infected and yields are seriously impaired. They are also an important source of inoculum from which there is spread to other varieties, which increases the likelihood of a breakdown of resistance.

The increasing numbers of whiteflies on cassava remain a serious problem in Uganda and other countries affected by the pandemic, in terms of both direct damage and increased risk of whitefly-borne viruses. The project plans to continue work on identifying sources of resistance through an extension of this CPP project and through the Tropical Whitefly IPM Project (R8041).

# Promotion of control measures for cassava brown streak disease

**R8227**

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August 2002–March 2005

See R6765, *Perspectives on Pests 1996–2000*, p. 13

Cassava brown streak disease (CBSD) poses a threat to food security in the coastal regions of eastern Africa. Because of its direct effect on root quality, CBSD is also a constraint to the development of commercial cassava processing. Good management of the disease increases the useable root yield of cassava, improving food security and allowing any surplus production to be sold directly or made into flour. Previous work and the current project have identified and promoted management of CBSD, which is caused by a virus, through the use of tolerant varieties, limiting losses to the disease until more resistant varieties can be made available. CBSD-tolerant varieties identified by the project have been distributed widely in Tanzania and Mozambique through village-based community multiplication, and via NGO food security projects and other rural development projects. For the first time, this project has been able to show that the virus causing CBSD is transmitted by the whitefly *Bemisia tabaci*. Thus in the future, host-plant resistance to whitefly may be used for control of CBSD along with the whitefly-transmitted cassava mosaic virus.

## ISSUES

Cassava brown streak disease (CBSD) has been shown to be a major threat to food security in the worst-affected areas of coastal eastern and southern Africa. Because of the associated symptom of root necrosis, the disease has a direct impact on both yield and root quality. A rural population of some 20 million people are affected by CBSD in the area extending from Kenya to the Zambezi River in Mozambique.

This project follows on from two previous projects on CBSD. R6765 established the incidence and distribution of CBSD; confirmed that it was still limited to altitudes below 1000 m; and showed that some local varieties were resistant to the associated symptom of root necrosis. CBSD was identified in Mozambique for the first

*Farmer harvesting tuberous roots infected with CBSD (photo: B. Khizza)*

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HILLOCKS, R.J. and JENNINGS, D.L. (2003) Cassava brown streak disease: a review of present knowledge and research needs. *International Journal of Pest Management* 49: 225–234.

MARUTHI, M.N. (2004) Bionomics, morphometrics and molecular characterization of a cassava *Bemisia afer* (Priesner & Hosny) population. *International Journal of Tropical Insect Science* 24: 323–329.

MARUTHI, M.N., HILLOCKS, R.J., MTUNDA, K. *et al.* (2005) Transmission of *Cassava brown streak virus* by *Bemisia tabaci* (Gennadius). *Journal of Phytopathology* 153: 307–312.

THRESH, J.M. and HILLOCKS, R.J. (2003) Cassava mosaic and cassava brown streak diseases in Nampula and Zambezia Provinces of Mozambique. *Roots* 8: 10–15.

UBWANI, Z. (2003) Devastating viral disease attacks cassava. *The Guardian*, 19 November, p. 5.


*Left, peeling cassava before drying (Mozambique); right, peeled cassava showing symptoms of CBSD root necrosis*

time. Project R7563 developed control measures and initiated a programme of on-farm research in Tanzania and established the extent of CBSD in Malawi. Field studies on the transmission and spread of CBSD suggested that periods of rapid spread coincided with periods of high whitefly populations.

Previous work has supported basic research on vector transmission of cassava brown streak virus, the cause of CBSD. Progress has been slow, although all the indications are that whitefly is the vector because of the close association between fluctuations in whitefly populations and the amount of virus spread. This research carried over into the present project.

Based on NRI's findings and earlier project work, the International Institute of Tropical Agriculture (IITA) has now recognised the importance of CBSD and has made resistance to the disease a priority for improved varieties intended for East African coastal areas. By the end of 2004 there were a number of cassava variety multiplication and distribution projects, in addition to this CPP project. There are now projects on CBSD supported by IITA, USAID and the Rockefeller Foundation in Tanzania, Mozambique and Kenya, all doing work based on the earlier findings of the CPP projects.

## ACHIEVEMENTS

The main focus of the present project was the promotion of control measures developed under R7563. Initial on-farm research into roguing and selection of planting material was abandoned because of farmers' hostility to roguing and an annual shortage of planting material. The project then focused exclusively on dissemination of CBSD-tolerant varieties, accompanied by an information campaign to raise farmers' awareness of CBSD symptoms and availability of tolerant varieties.

In the Southern Zone of Tanzania, on-farm validation of the tolerant varieties was completed in six target villages, and the emphasis with farmers' groups shifted to community multiplication. Secondary schools have also been involved, and community multiplication plots now form the focus for inclusion of cassava production and its uses in the school curriculum. Teachers from six schools received training at Naliendele. In addition, CBSD-tolerant varieties have been distributed to two villages in Rwangwa District at the request of the District Extension Officer. In all these villages the varieties have been multiplied and distributed.

In the Eastern Zone, the project has linked with the Eastern Zone Client Orientated Research and Extension (EZCORE) Project, funded by Irish aid and implemented by Muheza District Extension Office. They agreed to multiply the CBSD-tolerant varieties in their 30 contact villages. Project R8227 provided them with the initial planting material, and conducted on-farm

*Left, mild and below, severe leaf symptoms of CBSD (photos: James Legg)*

evaluation of the varieties in three villages close to Kibaha.

In Mozambique, technical assistance was provided to Save the Children, supporting its USAID-funded project to multiply and distribute CBSD-tolerant varieties. The project has also provided technical and financial support to the Mozambican National Root Crops Programme at INIA, to assist with its work to identify resistance to CBSD in local varieties and improved lines.

In Malawi, the project collaborated with SARRNET and the National Programme to make an initial collection of local cassava germplasm for resistance to cassava mosaic diseases (CMDs) and CBSD at Karonga Sub-station. A number of promising local and improved lines have been identified with tolerance to CBSD root necrosis, and one may also have some resistance to CMD. These lines were planted in on-farm trials in November 2004.

On-farm evaluation of the CBSD-tolerant varieties in Tanzania has shown that there is high approval among farmers for some of them. Kiroba, for instance, has proved very popular with farmers who market their cassava because of its early maturity and sweetness. An improved variety, Nal 34, has yielded well and also has good culinary characters. Nal 34 has been approved by the variety release committee as a CBSD-tolerant variety. These varieties will provide a temporary solution to CBSD until the IITA programme comes up with more resistant material. Their main drawback is susceptibility to CMDs.

The variety distribution programme has been supported by a communication strategy involving an information leaflet, posters and radio broadcasts. Extension officers in the Southern Zone of Tanzania have received training in all aspects of cassava production, crop protection and post-harvest utilisation.

*Root rot (left) and brown streak (centre) symptoms of CBSD, compared with uninfected cassava roots (right) (photo: B. Khizza)*

After several years of trying to transmit cassava brown streak virus (CBSV) with whiteflies, successful transmission with *Bemisia tabaci* was achieved in growth rooms at NRI, and the transmission confirmed by polymerase chain reaction diagnostics. The implication of this important finding is that host-plant resistance to whitefly may be considered as a possible method of dual control for CMDs and CBSD.

In December 2004, symptoms resembling those of CBSD were seen in Uganda. Leaf samples were sent to NRI and the presence of CBSV was confirmed. It appears that greatly elevated whitefly populations now occurring in Uganda have led to this outbreak of CBSD. This is the first time that substantial numbers of CBSD-infected plants have been reported in the Lake Victoria Basin and at altitudes above 1000 m.

## FURTHER APPLICATION

Now that resistance to CBSD has been made a cassava-breeding priority by IITA, continued funding for CBSD research beyond the life of the CPP project is assured. The new SARRNET programme will include CBSD in Malawi and Mozambique. The Rockefeller projects in Tanzania and Mozambique will continue after the end of the CPP project.

The Government of Tanzania is committed to increasing the acreage under cassava, and district extension offices are expected to implement this policy.

A large number of farmers and all district extension officers in the Southern Zone of Tanzania have been trained in disease recognition and control. Community-based multiplication has been established in contact villages and schools in the Southern Zone of Tanzania and northern Mozambique (with Save the Children), which requires no further input to be sustainable. Community-based multiplication will also be established in eastern Tanzania under the project extension.

Under extension R8404 the project teams mobilised funds for an emergency survey in Uganda, which confirmed fears that at least two TME (tropical *Manihot esculenta*) varieties widely distributed in Uganda (due to their resistance to CMD) were highly susceptible to CBSD. Following our report on this, survey steps are now being taken by the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and IITA to alert researchers in neighbouring countries to the threat from CBSD if these varieties are grown.

# Multiplication and distribution of sweet potato varieties with high yield and β-carotene content

**R8040**

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July 2001–June 2003

According to the 2001 Uganda Demographic and Health Survey and the WHO, vitamin A deficiency is a clinical problem in Uganda, with incidences of 30 and 50% among children and women, respectively. This project aimed to increase the multiplication, distribution, production and consumption of sweet potato varieties that are not only high-yielding and virus-resistant, but also rich in β-carotene (a precursor of vitamin A) – and thus to reduce food insecurity, poverty and malnutrition among small-scale farmers – in eight districts of Central Uganda.

## ISSUES

A shortage of improved varieties that are acceptable to farmers and consumers has long been a major constraint to sweet potato production in Uganda's Central Region, and throughout East and Central Africa. The situation is aggravated by a lack of formal systems to produce and distribute quality planting material. Poverty, a lack of proper links to markets, and limited post-harvest processing and utilisation are among the factors that greatly constrain sweet potato production, in addition to sweet potato virus disease – the most important disease limiting production in Uganda (see R8243, page 28).

In 1999, Uganda's National Agricultural Research Organisation

*Making sweet potato chips*

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AGFAX (2003) 'Chipping' in on sweet potatoes. May radio pack. www.agfax.net

AGFAX (2003) Processing sweet potato for poultry. June radio pack. www.agfax.net

NARO and CIP (2001) New sweetpotato varieties. National Agricultural Research Organisation, Uganda/International Potato Center, Lima (leaflet).

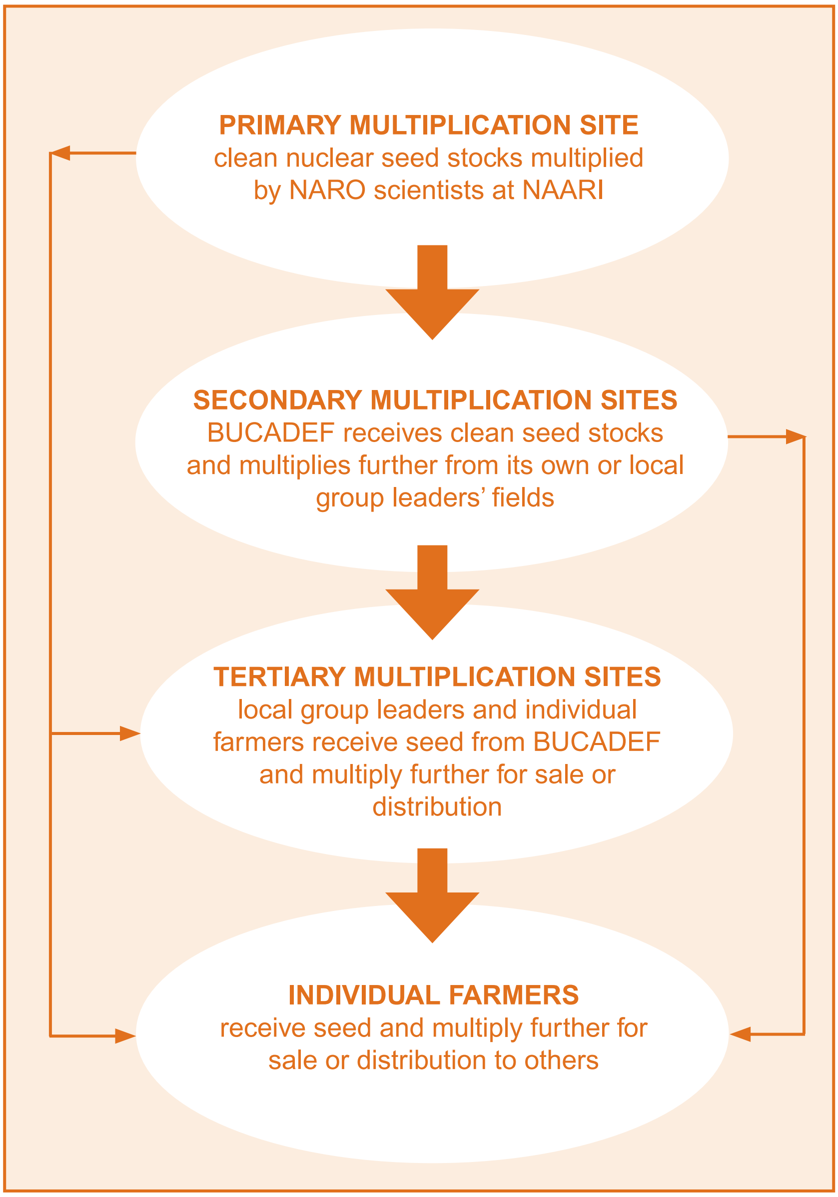
PRAPACE/BUCADEF (2002) The CPP-funded Sweetpotato Project with BUCADEF. Buganda Cultural and Development Foundation, Kampala/ SusRo Productions, Uganda. (Video, 14 min)

WREN MEDIA (2003) Eat up – it's good for you. *New Agriculturist on-line.* www.new-agri.co.uk/02-6/ focuson/focuson6.html

WREN MEDIA (2003) Sweet success. *New Agriculturist on-line.* www. new-agri.co.uk/03-2/pfeat/intro.html (picture feature).

(NARO), in collaboration with Centro Internacional de la Papa (CIP) and PRAPACE, released six virus disease-resistant sweet potato varieties with a production potential up to four times higher than the average for local varieties. One of these varieties is orange-fleshed and is rich in the β-carotene compounds that provide vitamin A.

With financial and technical support from PRAPACE/CIP and NARO, the NGO BUCADEF started an informal, farmer-based sweet potato planting material multiplication project. A year after that project's inception, 30% of BUCADEF's 3000 farmers had accessed the latest improved varieties and were multiplying them on over 170 hectares across eight districts. The interest expressed by farmers in the earlier project, the need to maintain links between the generators of the improved technology and the end-users, and the fact that the World Health Organization had categorised Uganda's vitamin A deficiency status in the clinical category, are the factors that led to the initiation of project R8040.




*The multiplication, distribution and uptake pathway*

## ACHIEVEMENTS

The project identified the current major limitations to the sweet potato sub-sector as: a shortage of clean planting material of improved varieties; poor links to market outlets; inadequate storage and processing techniques; lack of market information; lack of capital; control of unlicensed traders; and high transportation costs.

Decentralised, informal, farmer-based planting material multiplication farms were established in the eight districts. These farms are now operational, supplying quality planting material of improved varieties to farmers on a timely basis. They are becoming increasingly commercial – surprising in a region where sale of sweet potato vines was previously felt to be a social taboo. Producing sweet potato planting material for sale is highly profitable, bringing in up to 10 times more money than the sale of fresh roots, and contributing greatly to the sustainability of farms.

Improved varieties coupled with good management increased on-farm yields around threefold, providing better culinary characteristics and associated production returns. This resulted in in high levels of adoption (about 90%) for two varieties, one white-fleshed (Naspot 1) and the other orange-fleshed (SPK004), in the project target districts.

Some orange-fleshed sweet potato varieties that are rich in vitamin A, for example Naspot 5, are suitable for particular locations, while others such as SPK004 perfomed well in all districts. The varieties are now widely distributed in the districts of Central Uganda, where vitamin A deficiency is most pronounced. These districts are dedicated to multiplying the varieties more aggressively.

In the project's lifetime, the multiplication farms have disseminated at least 10 improved varieties to over 6000 other farmers, and have sold planting material estimated to allow planting of over 2000 hectares. In general, including multiplier effects, BUCADEF estimates that over 60% of the approximately


*One family in Luwero District was able to generate income that enabled it to shift from a grass-thatched hut to a larger, iron-roofed house, which they named 'NASPOT' after the improved sweet potato variety*

60,000 farmers that it serves in Central Uganda have received improved varieties. Consequently, on-farm productivity has tripled. It is conservatively estimated that over 34,000 tonnes of improved sweet potato worth over US$2 million were produced in the project area during its duration. The increased income has helped communities to improve their livelihoods, seen in such concrete evidence as living in better houses, owning more land, and sending more children to school, as well as having improved access to better food. Over 60% of planting material sold by secondary and tertiary multiplication farms was of the orange-fleshed type. Districts that are most affected by vitamin A deficiency were the most responsive in multiplying orange-fleshed varieties, which are gaining popularity, particularly among children and their mothers – the most important target groups. There is testimony that eating orange-fleshed sweet potato has improved the sight of children and the elderly, and has helped people living with HIV/AIDS. Factors that negatively influenced adoption rates were unavailability of credit, variations in consumer preferences, unavailability and high prices of planting material, and poor transportation facilities from farm to market and *vice versa*.

*In Luwero District, 78% of children interviewed preferred orange-fleshed sweet potato (a good source of vitamin A)*

The project brought together multiple partners in agriculture, health and nutrition to promote the adoption of orange-fleshed sweet potato varieties as a dietary source of vitamin A. Links were made with the Vitamin A Initiative for Africa (VITA A) project implemented by CIP in several countries in East and Central Africa.

The project also successfully introduced farmers to post-harvest processing to add value to their produce, for example by contributing to the successful production of Nutri-porridge by Maganjo Millers (funded by PRAPACE as a contribution to the project).

## FURTHER APPLICATION

The project was successful in establishing and strengthening inter-institutional links between BUCADEF and networks (PRAPACE, Foodnet), NARO, extension services, farmers, processors, international research centres and donors. This work formed the basis for a further DFID-funded project (R8273) in the Crop Post-Harvest Programme (CPHP), which was run by a coalition of 11 partners from various disciplines and managed by PRAPACE.

# Promotion of sustainable sweet potato production and post-harvest management through farmer field schools in East Africa

**R8167**

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April 2002–March 2005

Over many years, collaborative efforts of local and international agencies have focused on developing the components of sweet potato crop management in East Africa. This project brings together the most promising results from these studies into an integrated improved production and post-harvest management approach, with the aim of contributing realistically to higher yields, more reliable food security, and improved household incomes and livelihoods. The experiential learning approach of farmer field schools provides farmers with a deeper understanding of crop ecology and with observational, analytical and problem-solving skills that help them to evaluate existing and innovative practices. The formation of cohesive farmers' groups during these collective learning activities, and their exposure to economic analysis, increases the negotiating power of farmers with traders or suppliers, and leads to increased awareness of rights and the establishment of farmers' action networks.

## ISSUES

In East Africa, sweet potato is grown predominantly by women, both for home consumption and to supplement household income by sale in local markets and urban centres. In the past, sweet potato was consumed mainly in rural areas and its utilisation in towns was limited and often kept secret, as it was thought to reflect the low-income status of the consumer. However, with increasing urbanisation and health-conscious consumers, sweet potato is becoming increasingly important in urban food systems, and there has been a positive change in attitude towards the crop.

Constraints to production include lack of planting materials; a shortage of varieties that are high-yielding, early-maturing, drought-tolerant and high in dry matter and β-carotene content (R8040, see page 23); sweet potato weevil; sweet potato viruses (R8243, see page 28); low soil fertility; lack of markets and/or market information; short shelf life of fresh roots after harvest; and limited processing opportunities. These are often interrelated. This promotional project is one of four CPP sweet potato projects implemented between 2000 and 2005. Unlike the project that involved BUCADEF (R8040, page 23), it attempted to bring together as wide a range of research findings as possible and promote sustainable sweet potato production and post-harvest

*Promoting sweet potato (artist: William Temu, Mwanza, Tanzania*

*Products from orange-fleshed sweet potato: juice, crackies, doughnuts*

## SELECTED PUBLICATIONS

STATHERS, T., NAMANDA, S., MWANGA, R.O.M., KHISA, G. and KAPINGA, R. (2005) *Manual for Sweetpotato Integrated Production and Pest Management Farmer Field Schools in sub-Saharan Africa.* Kampala, Uganda: International Potato Center. ISBN 9970-895-01-X. 168 pp.

NAMANDA, S., KAPINGA, R., TUMWEGAMIRE, S., STATHERS, T.E. and VAN DE FLIERT, E. (2006) Dissemination and promotion of orange fleshed sweet potato varieties through FFS and VITAA partnerships: experiences in Eastern Uganda. *Proceedings of 13th Triennial Symposium of the International Society for Tropical Root Crops*, 9–15 November 2003, Arusha, Tanzania (in press).

NAMANDA, S., STATHERS, T., KAPINGA, R. *et al.* (2005) Promotion of sweet potato marketing and utilisation through improved chipping techniques: evidence from Abuket Sweet Potato Processors Association. Presented at the ISTRC-AB Symposium, Mombasa, Kenya. 1–5 November 2004.



*Farmer field school activities: above, checking root development, Okunguro FFS; top right, singing and dancing, Saasia FFS; bottom right, sharing agro-ecosystem analysis data, Undugu FFS*

management through farmer field schools (FFS) in western Kenya and north-eastern Uganda.

## ACHIEVEMENTS

Location-specific protocols, manuals and materials for sweet potato integrated crop management FFS were developed and field-tested via a process of three drafts. These incorporated or acted upon comments from all the different stakeholders who used the draft materials in the field during season-long field schools. The final version of the manual has been distributed to more than 1000 stakeholders, and is intended for use by field school facilitators (who may be extension staff, farmer facilitators or NGO/CBO staff facilitators).

Eighteen pilot sweet potato FFS were held (eight in Soroti, Uganda; 10 in western Kenya) involving 492 farmers, and four additional pilot schools were initiated as a self-financed spin-off activity in Kagera, Tanzania.

A training-of-trainers course on sweet potato pre- and post-harvest management was developed and refined through participant feedback. This practical course covers: sweet potato variety development; agronomy; disease and pest management; experimental design and data collection; facilitation and communication skills; planning; farming as a business; post-harvest processing and sweet potato product development. To date seven extension and one NGO staff have been trained as master trainers; 12 farmers have been trained as farmer facilitators and a further 15 identified for this role.

A wide range of diverse stakeholders have been involved in the project since it started, and many have been brought together annually at the project's planning and evaluation workshops. A stakeholder workshop was held in March 2005, to which individuals from other organisations with an interest in sweet potato and food security in Uganda and Kenya were invited. The participants gave presentations on their plans for integrating sweet potato FFS approach and activities into their own programmes, and a feedback system to enable progress in achieving the plans was developed.

Farmers were able to use what they had learned to improve household income and nutrition through:

- growing sweet potato varieties with high vitamin A content
- producing more sweet potato using the techniques learned
- testing different practices
- improved decision-making as a result of understanding how to base economic decisions on evidence they collect about their own activities
- selling products they have made from sweet potato
- linking to factories and setting up village-level quality processing units that function as profit-making businesses
- having improved access to planting material at the end of the dry season, and making a good profit by selling planting material of new varieties to other farmers at the start of the rains
- using different sweet potato recipes (*mandazis*, *chapatis*, juice, soup, etc.) to help increase income opportunities and to encourage their children to eat more sweet potato.

## FURTHER APPLICATION

The project also identified useful lessons in promoting promising technologies developed from research – one of the most important being the link between production and markets. A follow-on project (R8458) is currently supporting a further 37 sweet potato FFS in Uganda, Kenya and Tanzania, involving over 1000 farmers. A number of other organisations have or are implementing linked activities using skills initially acquired through this project: examples include the Ugandan National Agricultural Advisory Services programmes (Busia and Soroti); the NARO/DFID Client-Oriented Agricultural Research and Dissemination Project in Soroti; World Vision in Gulu and Kitgum districts; the GTZ/CIP project on mass dissemination of sweet potato planting materials in East Africa project; the Kenya National Agricultural and Livestock Extension Programme; the Rural Energy and Food Security Organization (REFSO); Africa Now; and projects in Tanzania and Zanzibar. The future of FFS in the region now lies in the hands of skilled farmer facilitators who are not only trusted by their farmer colleagues, but are also highly experienced and committed.

# Working with farmers to control sweet potato virus disease in East Africa

**R8243**

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*FAO Global IPM Facility, Kenya*

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November 2002–March 2005

Sweet potato is among the most important food staples grown in sub-Saharan Africa, particularly in East Africa. This project increased the productivity of sweet potato in East Africa by enabling farmers to grow the crop without the constraint of sweet potato virus disease and other pests and diseases. Farmers participated in selecting superior resistant varieties and seedling accessions, identifying appropriate cultural control measures and developing training tools and materials. Farmers and extensionists received resistant varieties and training in disease control methods.

## ISSUES

With good husbandry, sweet potato is among the most productive crops, but it can also yield on relatively poor soils. It requires few inputs except labour, and its ability to yield rapidly, and over a long cropping season, if harvested piecemeal, provides the flexibility to fit into a range of cropping systems. It produces a yield even when the rainfall pattern is irregular. Consequently, it is an important daily food for many farmers and their families in Africa, particularly resource-poor farmers growing food on a restricted area of marginal land. It can be important in disaster relief when other crops fail. Sweet potato is a cheap food for the urban poor in the growing conurbations of Africa, yet is also purchased by the growing middle class from supermarkets. By 2020, it is predicted that root crops will have an even more important role in food production in Africa than now and will be used in a more diverse range of products. Sweet potato virus disease (SPVD), a complex disease caused by synergism between a whitefly and an aphid-borne virus, is the most important disease of the crop throughout Africa. This CPP project on sweet potato viruses built on previous DFID and EU research investments and used participatory varietal selection methods as promotional channels.

## ACHIEVEMENTS

The project was based at national agricultural research institutes: Namulonge in Uganda and Maruku in Tanzania. Through collaboration

*Symptoms of sweet potato virus disease (front) contrasted with healthy plants*

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BYAMUKAMA, E., GIBSON, R.W., MWANGA, R.O.M., MPEMBE, I. and KAYONGO, J. (2004) Effect of shading and intercropping in management of sweetpotato virus disease in Uganda. Paper presented at the 9th Triennial Symposium of the International Society of Tropical Root Crops, October–November 2004, Mombasa, Kenya.

RWEGASIRA, G.M., MARANDU, E.F., GIBSON, R.W. and KAPINGA, R.E. (2004) Control of sweetpotato virus disease through farmer field schools approach in Kagera region, Tanzania. Paper presented at the 9th Triennial Symposium of the International Society of Tropical Root Crops, October–November 2004, Mombasa, Kenya.

with farmer groups (seven in each country), training was provided for facilitators and farmers through project staff, project-trained facilitators and exchange visits among the groups. This training process included knowledge of the causes of SPVD, how to control it by cultural methods, and the use and development of resistant varieties. The training also provided a test-bed whereby the project developed and validated training tools and materials.

Participatory varietal selection was conducted with farmer groups in both countries, testing nine and 11 cultivars in Uganda and Tanzania, respectively. These cultivars included high-yielding, SPVD-resistant and high-vitamin A orange-fleshed ones (see R8040, page 23). Farmers generally considered all varieties were useful: what did well in one location and one season did not necessarily do well in other situations. There were trends, however: the variety Naspot 1 yielded highly in most places and most situations; Naspot varieties were all generally very SPVD-resistant but some were *Alternaria*-susceptible. SPK004 was the most SPVD-resistant of the orange-fleshed cultivars. The project also identified more orange-fleshed local varieties as a contribution to the VITA A project (see page 23).

Interviews suggested that varietal resistance is the farmers' control strategy of choice, apparently requiring no change in work other than a new variety. Farmers were keen to receive a 'basket' of varieties to select from. However, in practice this is over-simplistic as the 'perfect variety' is elusive. Farmers are also all individuals with different preferences, priorities of use and customers. Good cultural control practices can help here by enabling farmers to grow more than just highly resistant varieties.

Farmers traditionally select healthy planting material, so the main cultural control tested was roguing.

*Sweet potato storage root derived from an accession selected by the participatory breeding process*

This was demonstrably effective, decreasing virus spread, increasing yield and improving the health of planting material. Isolation by distance and by a crop barrier was also tested. While both helped to control SPVD, isolation by distance was unsatisfactory because of land shortages and vulnerability of isolated crops, and the sorghum barrier seemed to reduce the yield of protected sweet potato. Simple phytosanitary guidelines (see below) were developed for extension and produced in poster form.

Until recently all sweet potato varieties grown in East Africa were landraces derived from occasional chance seedlings. Working with three farmer groups in Uganda and three in Tanzania, the project has made farmers aware of how new varieties develop. Farmers are involved in growing seedlings of superior families and then selecting them, with national programme breeders, through clonal generations in communal participatory breeding trials. They have also taken material to their own gardens to experiment. Farmers and scientists retain a small number of clones which appear to be high yielding, resistant to SPVD and *Alternaria*, and are monitoring them closely for other necessary quality attributes.

One general constraint highlighted by the close collaboration with farmers was the importance of drought resistance in sweet potato. Drought destroyed several

### Phytosanitation guidelines for controlling SPVD

- If possible, choose a variety or local cultivar that is not much affected by the disease.
- Collect cuttings for new crops from healthy plants.
- Select cuttings from healthy plants in crops in which few other plants have the disease; avoid collecting cuttings from very old crops because SPVD is less easy to see here than in vigorously growing crops.
- Remove any diseased plants as soon as they appear, especially in young crops.
- Plant new crops away from old crops.
- Avoid planting new crops where sweet potato was grown last season – storage roots and cuttings from old, diseased plants surviving in the soil will produce diseased plants from which infection will easily spread to your new crop.
- Ensure trash from old harvested crops, including unwanted storage roots, is destroyed.

*All these treatments will work better the larger the area in which they are used – so – work together with your neighbours.*

*Farmers in Luwero discussing whether or not to retain a particular accession*

participatory varietal selection and cultural control trials, and was identified as a major reason why some farmers did not continue growing the released varieties. It also severely affected the participatory breeding trials. One outcome of this is that the surviving selected accessions are likely to be drought- as well as disease-resistant.

In both Uganda and Tanzania, posters and leaflets explaining in different languages how to control SPVD were developed and used in training programmes for extensionists; a section on SPVD control was also included in a general farmer field school technical manual (see R8167, page 26). Extensive training was provided to extensionists in Tanzania, especially through a collaboration developed with Norwegian People's Aid. Planting material of superior varieties was also disseminated to refugee-affected areas in Kagera, Tanzania, and to refugees in Uganda.

The project has sustained the livelihoods of poor farmers in East Africa through a variety of measures, working directly with small-scale farmers, mostly women, and including refugees, farmers in refugee-affected areas, and families affected by HIV-AIDS. Planting material of superior varieties has also been provided to such groups.

Through a participatory approach, the project has validated the provision to farmers of a basket of superior, disease-resistant varieties, backed up by selecting healthy planting material and roguing of young crops. Participatory breeding has been tested for sweet potato in Africa for the first time, using a protocol developed to enable scientists and farmers each to contribute their own particular skills, resources and knowledge to the process. A few high-yielding, disease-resistant and drought-tolerant accessions have already been identified. These accessions show signs of being particularly well adapted to the low fertility evident in most farmers' fields, due to their selection under this environment. Sweet potato seems particularly suited to participatory breeding: its short generation time means results have been achieved quickly, and its easy vegetative propagation means there is no further variation of chosen accessions and there are ample cuttings to share among farmers.

## FURTHER APPLICATION

The project will continue with participatory breeding during an extension (R8457), maintaining close collaboration with national programmes in Tanzania and Uganda to achieve an easy hand-over of selected material. From this basis, the national programme in Uganda is continuing participatory breeding using funds provided by the McKnight Foundation.

The project will continue to work closely with other organisations, particularly in Tanzania, to disseminate project outputs more widely through the CGIAR Systemwide Tropical Whitefly Project.

# Characterisation and epidemiology of root rot caused by *Fusarium* and *Pythium* spp. in Uganda

**R7568**

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April 2000–March 2003

See R6651, *Perspectives on Pests 1996–2000*, p. 18

*Present address: Central Science Laboratory (CRL), UK

In the past 10 years, yields of common bean in Uganda have declined by about 50% due to declining soil fertility, insect pests and diseases, most importantly root rots caused by *Pythium*, *Rhizoctonia* and *Fusarium* spp. These fungi had not been well characterised in Uganda, yet this information is crucial for effective epidemiological studies, which can assist in developing sustainable disease management strategies. Using a combination of scientific and socio-economic research, this project took an innovative approach to the problem by determining the significance of interactions, not only between components of the pathogen complex causing the disease, but also between different farming practices and crop environments. The research has advanced current knowledge of the biology of the disease, its causal agents, their epidemiology and interactions with other bean pests and pathogens. Novel tools have been developed for rapid and reliable molecular diagnosis of *Fusarium* and *Pythium* to sub-species and pathotype levels; distribution of the pathogens in Uganda has been mapped; and management approaches evaluated. This project has increased both researchers' knowledge of farming practices, and farmers' knowledge of the causes of root rots, building up a receptive system for the promotion and adoption of management approaches that will stabilise and increase yields.

## ISSUES

Common bean (*Phaseolus vulgaris*) is the most important pulse crop in Uganda, grown throughout the country but especially in the south-west region. An important food to people of all income categories, beans are especially important to the poor as a source of protein, because animal protein is often rare or completely absent from their diets. In East Africa, beans are grown primarily by smallholder farmers (especially women) for home consumption, and any excess production is sold at market.

Thus beans play an essential role in the sustainable livelihoods of smallholder farmers and their families, providing both food security and income generation. In many areas there are several growing seasons a year, so crops are grown with minimal rotation and limited or no fallow period. This has led to a decline in soil fertility together with an increase in pest and disease pressure.

*A participatory farmer research group in Uganda*

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BURUCHARA, R., OPIO, F., OTSYULA, R. *et al.* (2001) Development of integrated management of bean root rots in East and Central Africa: past, present and future. Poster presentation at: PABRA Millennium Conference, 28 May–1 June 2000, Arusha, Tanzania.

MUKALAZI, J., BURUCHARA, R., ADIPALA, E. *et al.* (2002) Characterization of *Pythium* species pathogenic to common beans in Uganda. Poster presentation at: International Conference on Integrated Pest Management for Sub-Saharan Africa. 8–12 September 2002, Kampala, Uganda.

TUSIIME, G., BURUCHARA, R., ADIPALA, E., CARDER, J., SPENCE, N. and OPIO, F. (2002) Variation and detection of *Fusarium solani* from beans exhibiting Fusarium root rot disease symptoms. Poster presentation at: International Conference on Integrated Pest Management for Sub-Saharan Africa. 8–12 September 2002, Kampala, Uganda.

Beans showing chlorosis due to root rot

In south-western Uganda in 1994, bean production dropped to 25% of its previous level, dropping further to 20% in 1995. This drop in yield has been attributed to the effects of insect pests and diseases, especially root rot. Root rots are believed to be caused by one or more soilborne pathogens that act alone or as a complex depending on the environmental conditions. Pathogens that have been isolated from plants displaying root rot symptoms include *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctonia solani* and *Pythium* spp. The importance of root rots will continue to grow as the population pressure increases, resulting in greater cropping intensity. This project responded to the need to understand the disease aetiology and to diagnose the components of the pathogen complex in different bean-production areas.

## ACHIEVEMENTS

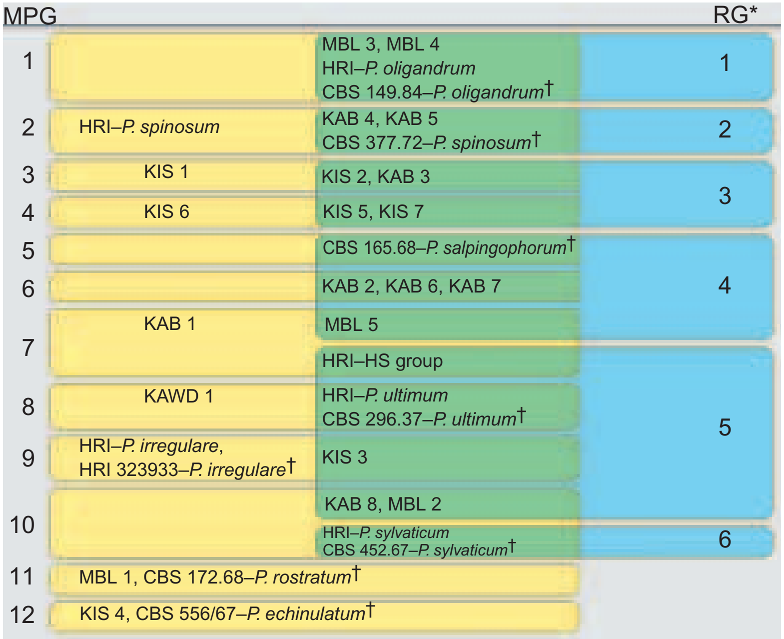
Studies were made of indigenous technical knowledge (ITK) of root rots, farmers' crop management practices and their perception of root rots. Farmer groups were established and training, knowledge transfer and resource supply were undertaken. Survey data were collected and analysed from Kabale and Kisoro districts, covering farmers' ITK; factors influencing disease; resource distribution; and communication systems. From the survey data, including studies of the information flow within communities, and the results of several participatory rural appraisals, dissemination methodologies suitable for effective technology transfer to resource-poor farmers were identified, and dissemination materials are under development.

Surveys were made of farmers' fields and large collections of root rot pathogens were established. Novel, rapid and reliable molecular diagnostic tools for the identification, differentiation and quantification of *Fusarium* and *Pythium* were developed, tested and applied to the pathogens collected. More work has followed to use the molecular probes successfully for identification and quantification of the pathogens in field soils (R8316, page 34; extension project R8478).

The distribution of *Fusarium* and *Pythium* spp. associated with root rots in Uganda has been mapped for the first time.

Interactions between root rot pathogens and other biotic factors

Bean plants displaying root rot symptoms




*Morphology (MPG) and restriction fragment length polymorphisms (RFLPs) by* Cfo*I,* Hinf*I and* Mbo*I (RG) groupings of 35* Pythium *strains. KIS=Kisoro; KAB=Kabale; MBL=Mbale; AWD=Kawanda; CBS=Centraalbureau voor chimmelcultures.*

influencing disease, including nematodes and bean stem maggots (*Ophiomyia* spp.), were investigated. In glasshouse tests, *F. solani* was a more damaging pathogen than either of two *Pythium* spp. A nematode survey revealed slight galling due to root-knot nematodes (*Meloidogyne* spp.) present in many fields, but severe galling was rare and there was no association between root rots and root-knot nematodes.

Management strategies for the control of root rot that are appropriate to resource-poor farmers were evaluated in terms of their effect on pathogen populations as well as their impact on disease. Several farmer-managed trials were established in community plots involving six farmer groups (with a total of over 100 members). These included participatory variety selection of root rot-resistant varieties, and fertility improvement using different types of manure. Materials and technologies of interest were then selected for use in farmers' individual plots.

The resistance to root rot of nearly 500 bean accessions was quantified in screenhouse trials and in farmers' fields. Over 300 germplasm entries were screened for resistance to *Pythium* root rot under artificial inoculation in a screenhouse. Accessions in a root-rot nursery (68 entries) and a segregating population (110 entries) were screened at the highland NARO station of Kachiwekano. Several potentially valuable accessions have been identified and will be subjected to further trials.

Dissemination methodologies suitable for effective technology transfer to resource-poor farmers were identified from several participatory rural appraisals and surveys of farmers' ITK and information flow within communities. The methodologies were evaluated using participatory approaches in community fields, which also served as learning plots for other farmers and groups. A modified farmer field school approach was used with two groups to address deficiencies in farmers' understanding of bean root rot disease.

The studies on farmers' working practices, technical knowledge and information flow proved invaluable in developing future strategies for reducing the impact of bean root rots on these resource-poor smallholder groups.

The project has trained Ugandan scientists to MSc and PhD level, and developed research protocols that will benefit researchers throughout the NARO. The knowledge, technologies and approaches to root rot management identified were promoted through project R7965 (see page 39).

## FURTHER APPLICATION

Further research inputs have improved the tools for quantification of pathogenic *Fusarium* and *Pythium* species in order to monitor and evaluate soil inoculum in relation to disease management practices (R8316, see page 34). A rapid, reliable quantification method is critical to epidemiological studies and to understanding how disease management practices affect the inoculum levels of pathogens causing root rot disease in the soil. The capacity for molecular diagnostics in the National Programme has also been enhanced. Additional studies on the interactions between pathogens (especially between *F. solani* and *Pythium* spp.) are ongoing (R8478) to elucidate their relative importance in field situations in Uganda. This research may also lead to opportunities for biocontrol.

This work will enhance the productive capacity of bean crops, particularly in Uganda, but also in countries where beans are grown under similar conditions, including Kenya, Rwanda and Tanzania.

# Bean root rot disease management in Uganda

**R8316**

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July 2003–March 2005

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An important food for people of all income categories, beans are particularly valuable to the poor as a source of dietary protein because animal protein is often limited in their diet. In East Africa, beans play an essential role in the sustainable livelihoods of smallholder farmers and their families, providing both food security and income generation. Root rots are the most serious constraint to bean production in Uganda, and the development of good management is limited by insufficient knowledge of the primary pathogens. This project built on previous research to develop a multiplexing polymerase chain reaction detection method for key *Pythium* species that are pathogenic to beans as well as other important crops such as sorghum and millets, often grown in association/rotation with beans. As a result, a quantitative assay (combining classical and biotechnology techniques) can now be adapted for the most important pathogens (e.g. *P. ultimum* var. *ultimum*), which can then be used to evaluate crop and management options on their inoculum levels in the soil. This will generate information on more effective options for integrated root rot management strategies. Information and techniques to assess how these options affect pathogen population levels have been generated, with prospects for application by researchers in the Pan-African Bean Research Alliance (PABRA) region.

## ISSUES

The intensity of bean production in Uganda is very high. In many areas there are several growing seasons a year, so crops are grown with minimal rotation and limited or no fallow period. These practices have led to a decline in soil fertility along with a rise in disease pressure caused by increasing pathogen inoculum levels in the soil. In south-western Uganda in 1994, bean production fell to 25% of its previous level, dropping further to 20% in 1995. Although this dramatic decrease in yield was attributed to the effects of a number of insect pests and diseases, root rot has now been identified as a major constraint to bean production. The problem is no longer restricted to south-western Uganda, and its control is now of high priority for the country.


*Bean root rot symptoms*

Root rots are believed to be caused by one or more soilborne pathogens that act either alone or as a complex of two or more pathogen species, depending on the environmental conditions.

Pathogens that have been isolated from plants displaying root-rot symptoms include *Fusarium oxysporum*, *Rhizoctonia solani* and *Pythium* spp. Previous research (R7568, page 31) developed molecular diagnostic tools for the identification and differentiation of *Fusarium* and *Pythium*. However, although progress in quantification was good for *Fusarium*, this proved to be more difficult for *Pythium*. Following on from the previous work, this project aimed to develop rapid detection and quantification methods for *Pythium* spp. to support the evaluation of resistant germplasm and disease management practices; to ascertain the role and significance of other crops within bean-based cropping systems in the development of root rots in order to allow sustainable integrated disease management; to characterise *F. oxysporum* f.sp. *phaseoli*, causing wilt disease in climbing beans in Rwanda; and to explore interactions between root-rot pathogens and other soilborne, disease-moderating organisms, allowing improvement of disease-management practices.

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MUKALAZI, J., ADIPALA, E., BURUCHARA, R., CARDER, J., OPIO, F. and SPENCE, N.J. (2003) Variation and identification of Pythium species associated with bean root rot disease in Uganda. In: *Proceedings of the VIth African Crop Science Conference, 12–17 October 2003, Nairobi, Kenya.* African Crop Science Society, Kampala, Uganda.

TUSIIME, G., BURUCHARA, R., ADIPALA, E., CARDER, J., SPENCE, N. and OPIO, F. (2003) Variation of *Fusarium solani* from beans with root rot symptoms inferred from AFLP analysis, pathogenicity and DNA sequences. In: *Proceedings of the VIth African Crop Science Conference, 12–17 October 2003, Nairobi, Kenya.* African Crop Science Society, Kampala, Uganda.

## ACHIEVEMENTS

A multiplex polymerase chain reaction (PCR) assay was developed for *Pythium ultimum*, *P. oligandrum*, *P. salpingophora* and *P. spinosum*. The assay was validated, standardised and optimised for the simultaneous detection of these species. A DNA extraction protocol that utilises skimmed milk was tested on different soil samples spiked with these species, and all species were successfully detected in the samples.

New probes were developed for *Pythium torulosum*, *P. deliense* and *P. nodosum*, for incorporation into the multiplex PCR detection system.

A quantitative PCR assay has been developed for *P. ultimum*, the most important *Pythium* pathogen causing bean root rot. Heterologous probes were developed and the assay tested.

The incidence and severity of root rots on crops were ascertained through surveys carried out in 16 sub-counties in Kabale District, including 22 crops and two common weeds. In the second season, additional surveys were carried out in 10 sub-counties and samples taken from 15 crops. A total of 180 samples were collected.

A range of symptoms (associated with *Pythium* root rot in the screenhouse) were recorded on different crops, notably sorghum, millets, maize, peas and beans. Initial characterisation of cultures isolated from plant samples using a semi-selective medium showed that nearly half the samples were *Mortierella* spp. Isolates considered to be *Pythium* came from Irish potatoes, sweet potatoes, sorghum, maize, beans, peas, millets and one weed species.

*Pythium* cultures have been characterised using restriction fragment length polymorphism (RFLP) and grouped into 10 classes. Representatives of these classes are being sequenced using oomycete universal primers, and the sequences compared with a *Pythium* sequence database.

Further studies using four *Pythium* species pathogenic to beans induced symptoms and damage on different crops to varying degrees. The crops most affected were beans, sorghum, millets, field peas and maize, in descending order, maize being least affected.

*Inspecting bean varieties in field plot in Kabale District, Uganda*

Observable symptoms included reduced root and shoot mass, root necrosis and shoot symptoms of deficiency (yellow and purple leaves). On-farm and glasshouse studies showed that major crops intercropped or grown in rotation with beans are affected by *Pythium* species pathogenic to beans, suggesting that they could serve as alternative hosts of the bean pathogens.

Second-season studies carried out on-farm confirmed that some soil amendments [farmyard manure, green manure, NPK and Ridomil (metalaxyl) fungicide], which are useful in integrated management of bean root rots, were also effective in reducing damage and increasing yield parameters in sorghum, millets, field peas and maize. The evidence obtained indicates that some crops intercropped or grown in rotation with beans are hosts of, or are infected by, *Pythium* spp. pathogenic on beans. Similarly, some organic and inorganic amendments influence the effects of bean root-rot pathogens on these crops, suggesting that use of amendments has broader effects on many crops.

The pathogenicity of isolates of *F. oxysporum* f.sp. *phaseoli*, causing wilt disease in climbing beans in Rwanda, has been determined. This will be a valuable tool in monitoring the spread of these isolates in the Eastern and Central Africa Bean Research Network (ECABREN) region. Pathogen- and race-specific primers have been developed to examine the molecular variation of *Fusarium* spp.

To evaluate the effects of beneficial interactions between root-rot pathogens and other soilborne disease-moderating organisms, different ways (form and timing) of deploying beneficial organisms (*Fusarium* spp.) were evaluated against *Pythium* spp. on beans under screenhouse conditions. Use of sorghum or millets as media for growing and deploying beneficial *Fusarium* spp. was promising.

## FURTHER APPLICATION

A fast and accurate quantitative assay for pathogenic species of *Pythium* would be very valuable in assessing the influence of management practices on inoculum levels and trends, and hence their effectiveness in managing bean root rots. Quantitative assay will also facilitate monitoring and assessment of the root-rot problem under different conditions, as well as the relative population of potential biocontrol species such as *P. oligandrum.* A follow-on project (R8478) is developing and adapting a quantitative assay (molecular and classical) for the characterisation of *Pythium* species that are pathogenic to beans, and that have potential as antagonistic or biocontrol agents.

# Participatory promotion of disease-resistant and farmer-acceptable *Phaseolus* beans

**R7569**

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March 2000–March 2003

See R6651, *Perspectives on Pests 1996–2000*, p. 18

*Phaseolus* beans provide affordable dietary protein for poor producers and consumers in both urban and rural areas. Diseases can cause substantial crop losses, but can be managed sustainably using appropriate disease-resistant germplasm, thus avoiding application of pesticides. This work aimed to disseminate improved varieties of common bean (*Phaseolus vulgaris*) resulting from previous CPP research in East Africa by giving farmers access to seed of appropriate, locally adapted varieties in sufficient quantities to meet demand. A bean variety (Urafiki), developed with farmers through participatory screening and assessment, was released in November 2003, and multiplied in sufficient quantities to fulfil the immediate requirements of the seed-release process. Seed-uptake pathways and distribution channels used by farmers were studied and project outputs prioritised according to farmers' requirements and incomes. The result should be improved food security where beans are grown for subsistence, and raised incomes in households where beans are grown as a cash crop. In urban areas better bean varieties will improve the stability of supply, and therefore prices, of this key component of the staple diet of the urban poor.

## ISSUES

Beans (*Phaseolus vulgaris*) are known in Tanzania as the 'meat of the poor', underlining the importance that farmers themselves place on the crop. Since the early 1990s, yields of common bean in East Africa have been declining due to reduced soil fertility, insect pests and a range of diseases. Bean landraces collected as part of farmer's bean mixtures (project R6651) were found to be resistant to several races of one or more major bean pathogens. Together with the activities of the Tanzanian national bean programme, this work produced a range of valuable germplasm. This material has been subjected to severe disease pressure to provide agronomically adapted seed lines for farmer participatory selection. A linked DFID project (R6670) revealed the complex management strategy used by farmers in the Southern Highlands, who use bean mixtures composed of between two and 25 components of different size, shape and colour. This knowledge formed the basis of the current project's studies of local requirements, communication strategies and uptake pathways.

*On-farm review of bean varieties*

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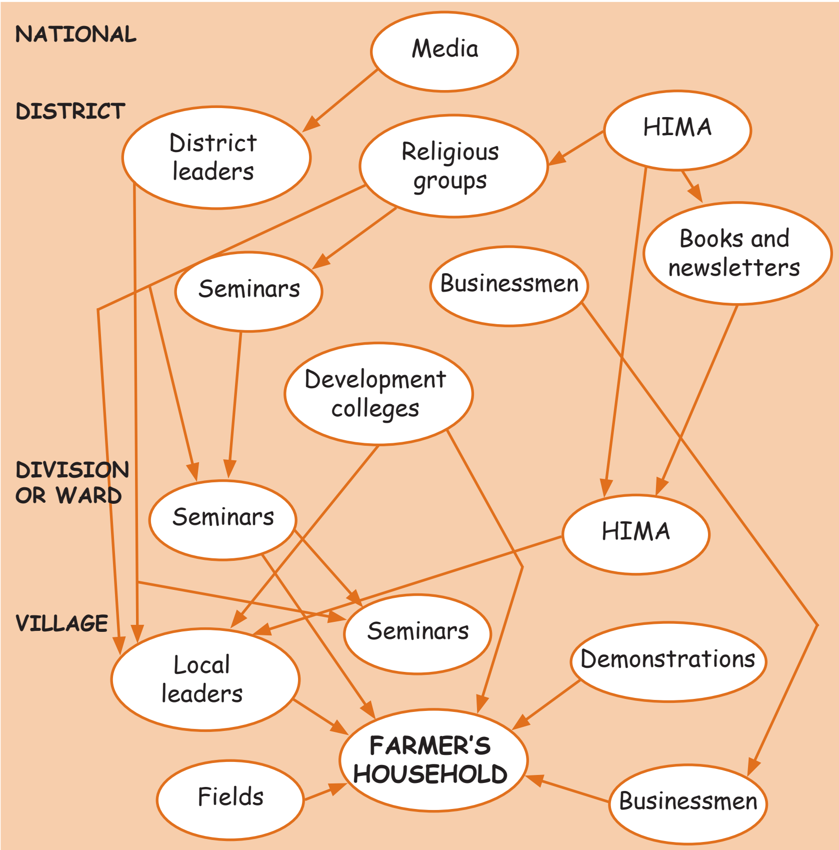


*A sample agricultural information network drawn up by farmers in Kifanyi [HIMA = DANIDA-funded Hifadhi Mazingira (Conserve the Environment) Project]*

Seeds are small packages of technology, and relatively cheap. They can be tried by farmers on a small scale without jeopardising their overall production. Studies (R6670) have shown that farmers are familiar with the management of genetic resources – especially women, who tend to be the seed custodians. This current project has continued the work to show that sustainable management of agricultural biodiversity is crucial to both increased food production and sound management of the environment.

## ACHIEVEMENTS

UK-bred bean lines, derived from locally adapted Tanzanian bean mixtures, have been selected under severe disease conditions at ARI-Uyole and assessed on-farm. Two seasons of agronomic evaluation of project-developed material resulted in the selection of eight promising bean lines from the 32 screened on-station. Activities moved on-farm to Lyadebwe with six participating farmers. Farmers' priorities were quantified in a participatory ranking exercise.

The variety Urafiki, released as a result of project activities, originated from a cross made in 1995 between Kabanima (5060/6) and Canadian Wonder. Kabanima (5060/6) is a bean mixture sub-component that was collected in 1991 from a farmer in the Southern Highlands of Tanzania. Canadian Wonder is a commercial variety that has large red seeds which are readily marketable. The new variety (Urafiki) combines adaptation to the severe growing conditions in Tanzania and resistance to a range of diseases with a desired colour shape and size of bean – it is well liked and readily marketable. Urafiki is well liked and readily marketable. Simultaneous participatory screening and assessment, both on-station and on-farm, means that farmers have ownership of this variety and has greatly increased the speed of varietal development.

After presentation to the Tanzanian Seed Research Committee, this variety was released in November 2003.

Crop diversity is often used as a means of stabilising yields. Smallholder subsistence farmers need sustainable yields that can be relied on year after year, and crops that are robust enough to provide some yield, even in poor seasons. Part of their coping strategy is the use of bean mixtures, which are fundamental to agriculture in the Southern Highlands of Tanzania and have withstood decades of political pressure to eliminate them. Only recently have researchers started to understand farmers' management of their biodiversity resources. This variety was developed to complement farmers' bean mixtures rather than replace them. It will enhance rather than replace agrobiodiversity, and therefore contribute to sustainable increases in crop yields.

Bean mixtures also contribute to maximising household income by decreasing production costs. These mixtures have diverse growth habits – bush, climbers and intermediate types are grown mixed together to produce a multi-dimensional crop canopy providing maximum light interception, and making optimum use of the land area cultivated and the water and nutrients available. This makes efficient use of resources, minimising the opportunity for weed competition. Thus weeding is minimised in this system, resulting in more efficient use of labour, with a consequent reduction in drudgery (for women). Farmers select their beans carefully to ensure they complement other bean mixture components, and the variety developed by this project is suitable for this use.

In addition, maximising the use of disease resistance minimises the use of crop protection chemicals, which are dangerous to both users and the environment, and expensive for resource-poor farmers to buy. Beans also fix much of their own nitrogen, thus reducing the requirement for artificial fertilisers.

A survey of seed-uptake pathways showed that farmers are interested in growth potential and yield potential, with only 6% of male respondents and no women making any reference to diseases. However, growth potential is highly negatively correlated with disease. The first effect of most diseases will be decreased seed germination, which will be noticed immediately by farmers. This means, however, that new varieties cannot be marketed directly on the basis of disease resistance, although this may have been the major force behind their development. Yield *per se* is not the most important attribute required by farmers: taste, seed-coat colour, cooking qualities and keeping ability are often more important. The project worked with farmers from an early stage to ensure that their performance criteria were met and to give them a sense of ownership.

The project also had a significant communication component. Increasing farmers' awareness of bean diseases so that they can take steps to minimise them has been addressed by production of posters and leaflets, which were distributed throughout the Southern Highlands of Tanzania, and by a radio programme on beans. Although copies of the posters and leaflets have been widely distributed to extension workers and NGOs, the process has highlighted some constraints to distribution. The general scarcity of print material and the perceived cost and quality of the leaflets combine to create reluctance on the part of extension staff (public sector and NGOs) to give them out to farmers. For similar reasons, posters are more likely to remain on the (internal) walls of extension offices than to be displayed in public places where they run the risk of being taken away or damaged by rain.

Existing sources of agricultural information were found to vary according to location and social and economic conditions. Informal contacts were the most important source of information about new bean varieties: for women, the market was most important whereas for men, friends and other farmers were preferred.

Although not the preferred source for new seed, research and extension services did score highly for the credibility of information. In order to retain this credibility, all new germplasm released and disseminated by research stations must be free of seedborne diseases.

Marketing of beans is increasingly important, both within Tanzania and in export markets to neighbouring Malawi, Zambia and the Democratic Republic of Congo. This variety, developed and tested in collaboration with farmers, is both appropriate for use as a component of local bean mixtures, and has also deliberately been bred to have a seed colour, size and shape which is suitable for marketing. At the same time it retains the adaptation to local environmental constraints of its parent Kabanima, collected as part of a local mixture in 1991.

## FURTHER APPLICATION

This project could only have been achieved using bean materials developed during project R6651 and the knowledge of bean mixtures and their management by farmers gained during the *in situ* project (R6670). The original bean cross was made in 1995, from a mixture component collected in 1991. By 2005 Urafiki had been officially released and the promotion project R8415 reports that 300,000 people now have access to this variety. The project has contributed to poverty reduction and enhanced the ability of smallholders to participate in commercial farming through making available this high-yielding and marketable variety.

*Selling beans at the local market*

# Promotion of IPM strategies for major insect pests of beans in hillsides of eastern and southern Africa

**R7965**

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April 2001–March 2005

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The project aimed to increase uptake of IPM technologies through improved dissemination strategies, in order to reduce losses caused by major bean pests in smallholder farming systems. This was achieved through surveys to improve understanding of the socio-economic characteristics that influence technology uptake in smallholder farmer communities, and of local knowledge systems and traditional IPM strategies. The project adopted a participatory group approach that helped create awareness of IPM among local community members and policy-makers. Participating farmers have accessed high-yielding, pest-tolerant beans and other crops, as well as improved cultural/agronomic practices that have helped raise production levels. Farmers in target areas have been linked to different partners to enhance their access to services and information (on markets, farm inputs, savings and credit, farm enterprises, etc.). The participatory approach, and the blending of indigenous and improved technologies, have restored farmers' confidence and empowered them in decision-making as well as raising awareness of other community members and policy-makers.

## ISSUES

Common bean (*Phaseolus vulgaris*) is an important food and cash crop in eastern, central and southern Africa. The crop contributes as much as 60% of dietary protein in Rwanda and Burundi, and about 30% in parts of eastern and southern Africa. Common beans are highly valued by the poor because all parts of the plant are consumed: the leaves are used as spinach and the grains are eaten fresh or dried, while the haulms (stems and pod shells) are a high-quality livestock feed. Although beans are grown largely for subsistence and mainly by women farmers, about 40% of the total production in eastern, central and southern Africa is marketed at an average annual value of US$452 million.

*Farmers benefit from improved bean varieties and agronomic practices*

Bean production intensity is greatest in highly populated hillsides, where farms are small and few other significant sources of dietary protein are available. The intensification of production in such areas has resulted in the elimination of fallow periods, soil fertility decline and high levels of insect pests (particularly bean stem maggots, *Ophiomyia* spp.; bean foliage beetles, *Ootheca* spp.) and diseases (root rots). These, together with frequent droughts, are the principal constraints limiting bean productivity in the region.

Collaborative research work by national research and extension systems in eastern, central and southern Africa, CIAT, the Eastern and Central Africa Bean Research Network (ECABREN) and AHI, has focused on developing and disseminating sustainable strategies for management of these pests. Strategies have included genetic resistance, chemical seed

*Farmer group in Dedza, central Malawi*

dressing, cultural practices to reduce population build-up, and integrated soil/water and crop management strategies to enhance plant vigour and tolerance of pests. Dissemination of some of these management strategies was already in progress in pilot areas of northern Tanzania in collaboration with the extension service and through AHI.

## ACHIEVEMENTS

The project adopted a participatory group approach, conducting sessions of group training for innovative farmers, extension officers, local leaders and other service providers in target locations. These were followed by on-farm participatory learning/ demonstration trials to study the biology and ecology of the major bean pests and diseases, effects of soil nutrients, etc. Farmer groups experimented with both traditional (wood ash, crude extracts from different botanical plants, soap and kerosene, cow urine and cowshed slurry, soil amendments) and improved crop and pest management technologies (cultural/agronomic practices, tolerant/resistant crop varieties, soil and water conservation practices, neem powder).

Robust and dynamic farmer groups (over 250 groups with more than 60,000 members in Malawi, Tanzania, Kenya and Uganda), plus additional groups in Rwanda and the Democratic Republic of Congo, were formed at project sites. Over 60% of group members are women farmers, who also play key roles in group leadership. The groups have been instrumental in planning and implementing major development activities in their respective communities. Group members have been very keen to learn by doing, and to share knowledge and experiences. Group-to-group visits have resulted in farmer-to-farmer dissemination of knowledge beyond the expectations of the project.

Researchers and extension personnel have developed a better understanding of the operation and needs of different types of farmers and farmer groups. Formal and informal group training, group demonstrations, participatory monitoring and evaluation, drama, radio, songs, poems, shows, displays, leaflets, posters, booklets and TV programmes were used by different groups to disseminate knowledge. Farmers' need for easy access to information within reach of their villages, and the retention of documents on their traditional knowledge and research results, led to the establishment of village information centres (VICs) – small community libraries stocking extension and other relevant reading materials. Currently there are 42 VICs operational at project sites in Uganda (1), Kenya (2), Tanzania (6), Malawi (1) and Rwanda (32). The VIC in south-western Uganda is in the same premises as a telecentre that was set up by the AHI project. Farmer group members and other individuals are using VICs to obtain knowledge. Innovative farmers have been training and catalysing the formation of new farmer groups at different sites in each season. Some farmer groups began researching on one constraint and, within a period of three years, were able to conduct studies on more than 10 constraints and became exposed to over six different partners. The promotional materials have been shared with national bean research programmes in Rwanda, Madagascar and the Democratic Republic of Congo.

The processes used in implementing project activities have attracted an increasing number of active partners (government ministries, NGOs, CBOs, other projects) who are now using the farmer groups to plan and implement development programmes in target communities.

Policy-makers from local government and political offices participated in project activities and have initiated cross-sectoral initiatives. In western Kenya, for example, the two VICs were partly furnished by the Ministries of Health and Education with interest in using such centres for HIV/AIDS awareness and adult literacy campaign activities, respectively. The Ministries of Agriculture in Kenya and Tanzania have used the project farmer groups as an entry point to projects such as the Participatory Development and Empowerment Project (PADEP) in Tanzania, where farmer groups develop proposals through the district authorities (or through the Kenya Agriculture Research Institute in Kenya) to compete for grants for farm inputs and promotion of research technologies. The Tanzanian Government has instituted a national policy on group approaches to planning and implementing rural development activities by different institutions.

Farmer groups requested various services and were linked to their respective partners at project sites. These partners included NGOs (World Vision, Concern Universal, Farm Africa, TechnoServe, Adventist Development and Relief Agency, PLAN International, Community Based Organisation Against Desertification, AFRICARE, CARE, etc.); extension and service agents (local government, private seed traders, etc.); and other special projects [AHI; CPP projects R7569 (p. 36), R7568 (p. 31), R8219 (p. 76), R8316 (p. 34); PADEP and the Agricultural Marketing Systems Development Programme in Tanzania, etc.]. The promotion of outputs from CPP projects R7568 and R7569 has widened the scope of project activities and stimulated farmers to demand more pest-tolerant materials, information on the availability of quality seed and training in seed multiplication. Recent links to R8219 have increased farmers' awareness of appropriate soil nutrient management for different crops.

*Farmers active in disseminating IPM strategies*

Some farmer groups have also requested information on markets, rural enterprises, training in various fields of production and visits/tours to share knowledge. In response to this demand, efforts have been made to link some groups to other CIAT projects (e.g. the Pan-African Bean Research Alliance, PABRA; ECABREN; the Southern African Bean Research Network, SABREN; the Enabling Rural Innovation initiative) and to interested local partners.

The participation and involvement of farmer group members has given farmers the confidence to identify production problems, search for solutions, experiment with options, monitor and evaluate the options, disseminate and share knowledge, exchange experiences with other farmers, and plan for future action. Farmers have been enabled to train others, implement research activities, collect information, and present reports clearly at farm level during field days up to regional workshop level. This process has encouraged farmers to take the lead in organising research activities and in disseminating information to other farmers and stakeholders at project sites, to the extent that the role of researchers and extension agents is now to provide backstopping services in response to farmer group demands.

The availability of both traditional and improved IPM technologies for bean pests was improved beyond the project target sites. Specifically, the socio-economic characteristics of IPM technology uptake and end-user benefits from participation in project activities have been determined and documented for Hai District in northern Tanzania.

Partnerships in project activities have enabled the participating farmers to increase farm production and have contributed to improved food security and household income, despite shortcomings such as frequent droughts and the increasingly high incidences of HIV/AIDS at project sites.

## FURTHER APPLICATION

Follow-up uptake studies on the socio-economic benefits of IPM technologies to bean farming communities have been conducted at target project sites in Malawi, Tanzania, Kenya and Uganda during April–November 2005.

# Epidemiology and variability of the coffee wilt pathogen

**R8188**

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August 2002–December 2004

Coffee wilt disease causes major damage to *Coffea canephora* grown by smallholder farmers in the Democratic Republic of Congo and Uganda. It also threatens production of *C. canephora* in Tanzania, although outbreaks are presently localised. The disease also occurs on *Coffea arabica* in Ethiopia, where it causes substantial losses in some areas. Project scientists collaborated closely with partners in a larger regional coffee rehabilitation and disease management programme (the Regional Coffee Wilt Programme, led by the Common Fund for Commodities). In this way a more comprehensive, regional perspective was gained on coffee wilt disease and the prospects for its future management. Important new knowledge of the wilt disease pathogen has been gained, particularly regarding pathogen variability, paving the way for research into resistant varieties, development of a rapid diagnostic technique, and advice on phytosanitary measures to limit disease spread.

## ISSUES

Coffee is Uganda's premier export, accounting for up to 55% of foreign exchange. Currently 70% of coffee-growing areas are affected by coffee wilt disease, and the Ugandan Coffee Developmental Authority has estimated that the disease is causing an annual financial loss per coffee-growing household of approximately US$63 (compared with a per capita annual income in Uganda of US$190). In Ethiopia, losses due to coffee wilt disease are patchy, ranging from 44% in some areas to 100% in others.

Coffee wilt disease (also known as tracheomycosis or vascular wilt of coffee) had been declining from the late 1950s, but the disease began to appear again in parts of Central Africa in the 1970s. Although it continues to be a problem on *Coffea canephora* in Uganda and the Democratic Republic of Congo (DRC), it does not appear to affect *Coffea arabica* in those countries. In Ethiopia the potential risk to *C. arabica* posed by the recent outbreak on *C. canephora* in Uganda and DRC needs to be assessed. Symptoms similar to those of coffee wilt disease have also been reported on *C. canephora* trees in the Kagera Region of Tanzania. If the disease has indeed spread to these areas of Tanzania from Uganda or elsewhere, the aetiology, extent and severity of the outbreaks need to be determined, and efforts to limit further spread must be put in place.

*Defoliation caused by coffee wilt disease*

The aim of this project was to acquire new knowledge of genetic

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*Sampling weed species for the presence of* F. xylarioides

and pathogenic variability within the coffee wilt disease pathogen, *Fusarium xylarioides* (teleomorph *Gibberella xylarioides*), and of the mechanisms of pathogen transmission and infection in relation to disease spread. This knowledge will be of great value in the search for durable resistance and generally enable more appropriate, effective and sustainable cultural management options to be made available for validation, including validation by farmers. As part of the broader Regional Coffee Wilt Programme in Africa, it will ultimately enable strategies to be developed to reduce the impact of coffee wilt diseases, helping to stabilise smallholder coffee productivity in target countries.

## ACHIEVEMENTS

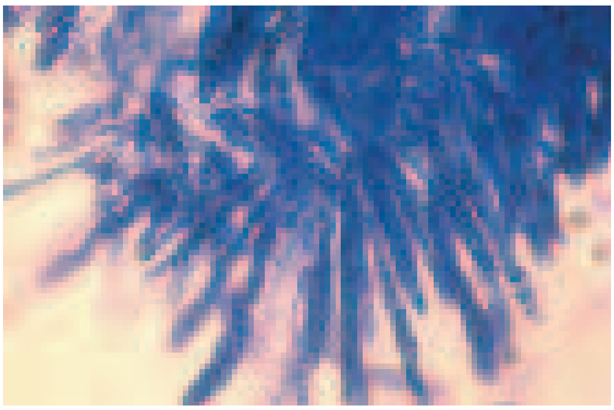
A number of very significant findings emerged from the project. In-depth genetic analysis of the pathogen revealed that, while overall variation is limited, the ongoing coffee wilt disease endemic in Ethiopia and the recent, highly destructive outbreak on robusta coffee in other parts of East and Central Africa comprises two forms of *F. xylarioides*. The first (type A) is found only in Ethiopia and only on *C. arabica*; the second (type C) occurs in Tanzania, Uganda and DRC, and only on *C. canephora*.

Variability within each of these two groups is very limited, suggesting that they may represent two clonal lineages. Studies of pathogenic variability also revealed that type A is pathogenic only to *C. arabica* variants, while type C is pathogenic only to *C. canephora*. The minor genetic differences observed between these two forms, which preliminary studies indicate may be caused by DNA insertions or deletions, may be linked to pathogenicity traits.

These findings have considerable implications for the search for host resistance to coffee wilt disease, as the genetic base within the pathogen appears to be relatively narrow. Theoretically, coffee possessing resistance or tolerance to a type A isolate from Ethiopia should show this trait against any type A isolate, at least within Ethiopia. Similarly, resistance or tolerance to a type C isolate from Tanzania, Uganda or DRC should exhibit this characteristic when challenged by isolates from throughout this region.

Host specificity operating within the pathogen may also explain why coffee wilt disease was not encountered on *C. arabica* in Tanzania or (although cultivation is limited) on *C. canephora* in Ethiopia. In-country studies of pathogenic variability within the two *F. xylarioides* forms were not possible during the project, and further information on host specificity and aggressiveness in particular would be useful. If the genetic variability observed between the two forms of *F. xylarioides* is based on differences at specific DNA sites (for example an intron or deletion), the prospects for developing a rapid, DNA-based diagnostic technique are good.

This research has also helped to clarify the mechanisms of coffee wilt disease transmission and disease spread. Initial data generated by a number of small-scale on-farm and on-station trials suggest that wounds made with a machete previously used to cut infected coffee wood are sufficient to induce wilt disease development on healthy coffee, at least in mature trees. Coffee wood, an important source of fuel for farmers, can also act as a source of infection to young coffee seedlings if the wood is already affected by wilt disease, while infested field soil can remain infective to seedlings for at least three months after removal of an infected coffee tree. Despite speculation that insects may play a role in transmission of *F. xylarioides*, the fungus was not found on the body parts of a range of insects commonly found on coffee farms and associated with coffee, including coffee pests, bees and termites. Nor has the fungus



*Ascospores of* Fusarium xylarioides

*Setting up screenhouse trials to assess pathogenicity of the coffee wilt disease pathogen*

been found on a wide range of possible alternative hosts, including crops commonly cultivated alongside coffee, or on weed species occurring on coffee farms.

Isolation of *F. xylarioides* from soil, as an indicator of the existence of viable propagules of the pathogen, proved a problem throughout the project. Development of coffee wilt disease symptoms on seedlings raised in soil was (albeit based on somewhat circumstantial evidence) found to be the only means of confirmation. Successful development of a DNA-based diagnostic technique would constitute a major step forward, but still would not allow differentiation between living and non-living fungal material. Further research is required on this aspect.

Through the project, a large and comprehensive collection of *Fusarium* species from coffee was established at CAB International Africa Regional Centre, Nairobi, while smaller collections were also developed in Ethiopia, Tanzania and other countries affected by the disease. These collections provide the backbone for research on coffee wilt disease, and constitute an extremely useful resource for future research initiatives. It is imperative that they are adequately maintained and, where feasible, built upon.

## FURTHER APPLICATION

The new knowledge generated by this project will support the development of more appropriate, effective, applicable and sustainable management strategies for coffee wilt disease. The project outputs can be taken up by national coffee improvement programmes for validation, promotion and implementation. This will be achieved under the auspices of the multidonor Common Fund for Commodities/EU Regional Coffee Wilt Programme in which a component is devoted to the validation and promotion of improved methods for farmers to manage coffee wilt disease, and which specifically addresses the development of extension programmes and training for small-scale coffee producers. This component is, in part, directly dependent on the knowledge generated by this project, and that of the linked International Cooperation with Developing Countries (EU) project (Development of a long-term strategy based on genetic resistance and agro-ecological approaches against coffee wilt disease), coordinated by CIRAD. Regional workshops are held each year to summarise outputs from the linked projects, identify those suitable for extension and dissemination, identify promotional pathways and allocate resources to promotional activities.

The project outputs will enhance the capacity of farmers and those who support them in the struggle against coffee wilt disease. By doing so, they will help safeguard future coffee production in Africa; maintain a vital source of revenue for resource-poor farming communities and others dependent on coffee production; and stabilise national economies that depend on the crop as an income-generating commodity.

# IPM for smallholder coffee farmers in Malawi

**R8204**

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September 2002–March 2005

In the remote hillside farming systems of northern Malawi, coffee is one of the few options for cash cropping. Yields are among the lowest in the world but, despite the low world price for coffee, there is a market for 'Mzuzu' coffee because of its high quality. Following on from earlier work to identify the pest constraints, this project promoted control measures within an ICM framework. On-farm demonstrations were used to promote an ICM system based on growing a derivative of the improved variety Catimor 129 (known as Nyika), which is resistant to the two major diseases. On-farm trials to evaluate insecticides led to the approval of fipronil for use on coffee. This project has contributed to the rehabilitation of smallholder coffee in Malawi at a time when the estate sector is abandoning coffee in favour of other crops. The smallholder sector is expanding rapidly with the assistance of the EU, and the SCFT expects the crop to be sufficient to sustain this trade organisation from export levies by 2007. The project has contributed to the sustainability of the sector by promoting ICM for a farming system (coffee × banana intercropping) that is favoured by farmers, and which provides a food crop as well as a cash crop. Work with perennial crops over a relatively short time frame is always challenging, but this research has made significant steps in addressing some of the primary constraints facing Malawian smallholders.

## ISSUES

The earnings from coffee sales are a vital part of the livelihood strategy for rural communities in the hillside farming systems of northern Malawi. Whereas the bulk of coffee production comes from large estates in the south of the country, and the estate sector has some of the highest yields in the world, the smallholder sector averages one of the world's lowest yields – but some of the coffee is of high quality. Since 2002 the smallholder sector has been expanding at a time when, due to the low world price, coffee output from estates has been declining as they diversify into other crops such as tea and macadamia nuts. This smallholder expansion has been supported by EU funds to the SCFT for capacity building and the multiplication and distribution of new (Catimor) coffee varieties.

CPP support for coffee IPM in Malawi began in 1996 (R6807), just as the smallholder sector entered a period of conflict and change. At that stage the smallholder sector was in turmoil, with poor prices being paid to farmers and

*Catimor coffee × banana intercrop – demonstration plot*

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The hedgerow system for growing Catimor varieties of coffee

coffee gardens neglected. Coffee smallholders supported an industry restructuring and the establishment in 1999 of the SCFT. This trade organisation was to be funded eventually from export levies, but was initially supported by the EU. When the present project began in September 2002, the SCFT was focusing its efforts on Catimor growers. Although most of the new Catimor varieties were yet to come into bearing, the work described here responded to demand from farmers to promote disease-resistant Catimors as a component of the IPM system. This aimed to ensure that the IPM/ICM messages developed over the years were promoted through extension literature, on-farm demonstrations and farmer training.

## ACHIEVEMENTS

An ICM system that met smallholders' requirements was developed and promoted as one of a basket of crop management options for the new dwarf Catimor varieties. Varieties promoted by the EU project were resistant to coffee leaf rust (*Hemileia vastatrix*), but not to the other main disease, coffee berry disease (*Collotetrichum kahawae*). The project advocated the use of a selection from Catimor 129 (known as Nyika) that was resistant to both diseases, but supplies of seed were scarce. A mother garden of Nyika trees was therefore established to meet the demand for seed. On-farm demonstrations of Nyika intercropped with banana were used to promote the technology direct to farmers, backed by an information campaign using leaflets in local languages.

White stem borer (*Monchamous leuconotus*) is the major insect pest in the region, and is a threat to coffee rehabilitation based on Catimor varieties. On-farm trials to evaluate insecticides led to the approval of fipronil for use on coffee.

Socio-economic research focused on growers' management practices for Catimor coffee, the economics of chemical control for stem borers, and the impact of Catimor coffee on livelihoods, particularly for poorer growers. A study of management practices showed that early ICM adopters had closely followed recommendations on terracing, mulching, manuring and frequency of weeding. But growers generally had not adopted recommended practices about hedgerow planting, planting in pure stands, or the use of lime and Compound J fertiliser (NPK plus sulphur in the ratio 15:5:20:6). Nitrogen application rates were above recommended levels. This suggests that there is considerable scope to improve the efficiency of fertiliser use and thus reduce the costs of fertilising coffee.

Farmers' evaluation of chemical control using stem paints was positive, but formal economic evaluation showed that benefits discounted at 15% over an eight-year coffee cycle were lower than costs. Application rates in on-farm trials are therefore not profitable at current rates and given current knowledge of borer infestation rates. This analysis is provisional as full information on infestation rates is not yet available, and it may prove feasible to apply stem paint every two years rather than every year. Nevertheless, these results suggest the need to continue efforts to identify control methods that may be less effective, but more affordable and economically viable.

An impact survey over the first four years of Catimor adoption showed positive impacts on livelihoods, including accumulation of assets, improved food security, and greater demand for hired labour at weeding and harvesting. Women in adopter households often planted their own coffee gardens to ensure a protected source of income. Households with more Catimor had lower incomes from bananas, reflecting the SCFT recommendation to plant Catimors in pure stands. This confirms the importance of current trials to develop recommendations for intercropping coffee with banana.

## FURTHER APPLICATION

A nine-month follow-up project (R8423) is working to promote these findings to the much larger coffee smallholder sector in Tanzania.

# Implementation of cocoa IPM in West Africa

**R8313**

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July 2003–March 2005

See R6656, *Perspectives on Pests 1996–2000*, p. 47

Much work has been carried out on specific pest and disease problems in cocoa, but much of this knowledge needs to be made available to farmers. In partnership with the STCP in West Africa, a farmer participatory training and research programme was initiated in three countries to evaluate and disseminate outputs from previous CPP projects on cocoa IPM. Research activities included the development of a tailor-made farmer participatory learning curriculum. The project played a major role in the start-up phase of farmer field school activities, and contributed a range of technical IPM bulletins and field guides for use by farmer facilitators and master trainers. Models for optimising management inputs to cocoa production were adapted for West Africa. Farmer field research activities were supported in Nigeria, Cameroon and Ghana, on rational pesticide use against black pod disease; evaluation of biological control agents for black pod; and evaluation of pheromone traps for cocoa mirids, respectively. Farmers greatly appreciated the cost savings that could be made using more targeted (bio)pesticide application methods. Through collaboration with regional SCTP and national research institutions, new IPM knowledge from previous research has been effectively evaluated by farmers and disseminated through participatory learning.

## ISSUES

More efficient transfer of technologies (knowledge transfer) is needed to achieve real benefits from research efforts into sustainable cocoa production. The classical 'top-down' manner of transferring blanket recommendations is being largely discarded, with increasing attention being paid to farmer participatory models of knowledge dissemination. Farmer training should take a holistic approach to the farming system, and research needs to focus on problem-solving by farmers and effective research–extension–farmer partnerships.

*Testing the trombone sprayer, Nigeria*

Previous CPP projects on cocoa production include: modelling of management inputs for cocoa production (R6656); spray application against black pod (R7326); biological control agents against black pod (R7249); and pheromones of cocoa mirids (*Distantiella theobroma* and *Sahlbergella singularis*) (R7249).

The STCP was created in 1998 by USAID and industry, aiming to achieve a shared vision for sustainable tree crop development. It is a public–private partnership between industry, producers, researchers, government agencies, public sector institutions and conservation groups. The STCP started with pilot implementation activities early in 2002, which almost coincided with the start of this project. Collaboration was sought for the project to assist STCP with its curriculum development and participatory technology development work, and for this project to be part of a larger framework, leading to a unique cooperation and coordination of field activities among all partners involved.

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VOS, J.G.M. (2003) Practising cocoa IPM – current developments and needs in farmer training for IPM implementation. pp. 153–158. In: *Proceedings of 4th International INCOPED Seminar on Cocoa Pests and Diseases,* Accra, Ghana, 20–21 October 2003. Akrofi, A.Y., Ackonor, J.B. and Ollennu, L.A.A. (Eds). International Permanent Working Group for Cocoa Pests and Diseases.

Website: www.treecrops.org

*Demonstrating run-off with a conventional high-volume cone nozzle in Cameroon (photo: R. Bateman, International Pesticide Application Research Centre)*

## ACHIEVEMENTS

A farmer participatory learning curriculum for cocoa IPM in West Africa has been produced. A wide range of participatory exercises was compiled and validated with master trainers and farmers during curriculum-development workshops and in pilot farmer field schools (FFS). Many of these were written up as straightforward protocols, and included in a manual that will form the base curriculum for the STCP master trainers. Local adaptation and expansion of the curriculum have taken place.

Several modules of the finished cocoa-production model have been developed, including a shade module that will allow users to explore the impact of shade intensity and 'gappiness' on three primary pests of West African cocoa: mirid bugs and two black pod fungi. Shade intensity has impacts on both mirids and black pod, but more importantly on the latter. The gappiness aspect of shade allows the mirid population model to be compartmentalised for an improved description of population dynamics and management. This module will allow the user to simulate shade management and to assess the costs and benefits that shade manipulation may have for farmers. Climate-based vegetative flushing (or growth) models have been developed that are relevant to the population dynamics of pest populations based on historical weather data. The most important inhibitory factors to vegetative flushing are drought and low temperatures. The flush model interacts with flower setting and cherelle wilts in the age-structured pod model, which interacts with the flush model when large numbers of rapidly growing pods (90–120 days old) inhibit the size of climate-induced flushes. The model simulates the start of 'normal' floration as occurring at a fixed time after a leaf-hardening period following a new vegetative flush. It is expected that, by including these phenological aspects, different varietal responses to climatic and phenological cues will improve the value of the model.

The project developed IPM technical bulletins for the major cocoa pests in the region, to be translated into French and handed out to farmer trainers as information leaflets. The project also contributed to exercise protocols and advisory documents, especially on rational pesticide use and testing of biocontrol agents. Through workshop participation and facilitation, further documentation of participatory training processes and methods was made available to trainers within the STCP. All these guidelines will be incorporated in the STCP manual (in English and French) – Learning about sustainable cocoa production: a guide for participatory farmer training. The manual contains technical bulletins, discovery learning exercises and field guides.

The project provided support to the STCP knowledge-transfer specialist in initiating farmer participatory training activities through awareness-raising, planning and curriculum development workshops, and through advice on participatory research activities, impact assessment, self-financing field schools, simplified statistics, etc. Farmer innovations and experiences in the STCP context and with various other stakeholders were documented through participatory video production, so that these experiences can be disseminated more widely. Farmer field research activities were supported in Nigeria, Cameroon and Ghana. This collaboration was channelled directly through the Cocoa Research Institute Nigeria (CRIN); the Institut de Recherche Agricole pour le Développement (IRAD) in Cameroon; and the Cocoa Research Institute Ghana (CRIG). STCP master trainers were trained to facilitate farmer field research, and an agreed action plan was implemented in the three countries:

- in Nigeria, the focus was on black pod control through rational pesticide use to improve on the current use of self-made fungicides applied with trombone sprayers
- in Cameroon, farmers were involved in evaluation of biological control agents in the search for more effective management of black pod

*Observing a biocontrol agent-treated cocoa tree to observe efficacy of black pod control, Cameroon (left). Added value was achieved through a partnership with industry to pilot participatory video production (photo: STCP)*

- in Ghana, farmers worked with scientists to evaluate the use of mirid pheromones to look for innovative ways of avoiding mirid damage during peak seasons.

Spray-application techniques were investigated in participatory research with scientists and farmers in Nigeria and Cameroon. In Nigeria, working with CRIN, the focus was on improvements to the spray equipment to improve the targeting of fungicides and to reduce fungicide waste, thereby reducing environmental pollution. In Cameroon, working with IRAD, the focus was on applying a biological control agent and comparing this with improved methods of applying regular fungicides. Both scientists and farmers have reported enthusiastically on the scientist–farmer collaboration. Improvements were achieved in farmers' understanding of the importance of spray equipment in making an impact with pesticide applications; reducing pesticide waste; and reducing input costs – and in scientists' understanding of farmers' real needs. Over the project period, STCP implemented FFS in pilot areas using the jointly developed curriculum in Cameroon, Côte d'Ivoire, Ghana and Nigeria. In 2003 a total of 160 FFS were implemented, training 3734 farmers; in 2004, 127 FFS for 3780 farmers were held.

Advisory visits were made to support the planning and design of protocols to test biological control agents with IRAD in Cameroon. Field application was carried out by technical assistants, using full protective clothing, and evaluation was done in close consultation with farmers. Farmers were most interested in the biological control methods, which scientists clarified using various participatory exercise protocols. Advice was given on eventual mass production and quality control of efficacious agents, and on the laboratory facilities needed. An expected bottleneck might be the registration of successful biocontrol agents, and IRAD has been made aware of this.

In collaboration with CRIG in Ghana, pheromone blends and trap designs were optimised for the main mirid species in Ghana. Lures last for at least six months in the field, and traps can be used for several seasons with little maintenance. Monitoring with these traps showed that significant populations of mirids are present well outside the generally perceived 'mirid season' of August–December. Trials using the traps for mirid management by mass trapping were carried out in farmers' fields at three different trap densities. Results showed little evidence for a reduction in mirid numbers or damage, probably partly due to the small scale of the experiments. Farmer field research was initiated rather late in the project lifetime due to delays in formalising the CRIG collaborative agreement. However, this has now been secured and is in progress in collaboration with STCP and also at other sites regularly used by CRIG for farmer extension.

## FURTHER APPLICATION

An industry co-funded CPP extension project (R8448) is focusing on exploring participatory video as a tool for consolidation and sharing of IPM lessons from cocoa FFS, and making the benefits of cocoa mirid pheromone research available to a wider cocoa-growing public. This is being achieved through a farmer participatory training and research programme in collaboration with STCP.

# Pheromone traps and new technologies for control of cowpea pests in West Africa

**R8300**

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April 2003–March 2005

See R6659, *Perspectives on Pests 1996–2000*, p. 56

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DOWNHAM, M.C.A., TAMÒ, M., HALL, D.R., DATINON, B., ADETONAH, S. and FARMAN, D.I. (2004) Developing pheromone traps and lures for *Maruca vitrata* (F.) (Lepidoptera: Pyralidae) in Benin, West Africa. *Entomologia Experimentalis et Applicata* 110: 151–158.

RUREMA, D.G., ATACHI, P., TAMÒ, M., DOWNHAM, M.C. and DATINON, B. (2003) Relation entre les infestations larvaires et les vols des adultes de *Maruca vitrata* (Fabricius) (syn: *M. testulalis* Geyer) (Lep: Pyralidae) dans les cultures de niébé (*Vigna unguiculata* (L.) Walp.) sous l'attrait des phéromones. *Annales des Sciences Agronomiques du Bénin* 1(6): 61–75 (in French).

Cowpea provides a cheap source of dietary protein for low-income urban and rural populations in West Africa, but is prone to insect pest attacks. On-station trials for control of these pests in Benin and Ghana built on earlier work to show that a variety of botanical pesticides, with or without pheromone traps for the legume pod borer *Maruca vitrata*, were intermediate in effectiveness between conventional (expensive and environmentally damaging) pesticides and untreated controls. Neem seed oil was the best botanical for controlling flower thrips and pod borer. Farmer field school trials confirmed these findings, and recommendations were developed for the optimal use of traps. Approximately 500 farmers in 26 villages now have detailed experience of the technologies, with many expressing willingness to pay economic costs. These farmers will form a core market for future commercial development.

## ISSUES

Cowpea (*Vigna unguiculata*) is a highly important grain legume crop grown in West Africa. The crop is grown mostly in subsistence farming systems and on a small scale in the lowland dry Savannah and Sahelian regions. it is an important source of dietary protein, and also a vital cattle forage crop. Africa produces 75% of world cowpea production, of which the majority comes from West Africa.

The legume pod borer *Maruca vitrata* (syn. *Maruca testulalis*) is a key pest of cowpea and other legume crops. In West Africa *M. vitrata* forms one of a complex of damaging insect pests of cowpea, which can also include aphids (*Aphis craccivora*), foliage beetles (*Ootheca mutabilis*), several species of pod bugs, and legume bud thrips (*Megalurothrips sjostedti*). The cost of insecticide limits its use by many poor farmers. In cotton-growing areas of Benin, farmers often use cotton insecticides (sold at subsidised prices), which are not recommended for cowpea, applied on a calendar basis, resulting in health and environmental hazards.

*Pod borer damage on cowpea; inset: larva of* M. vitrata

Recent research efforts, mostly led by the International Institute of Tropical Agriculture (IITA), have been directed to developing resistant varieties and biological control against key cowpea pests. A viral pathogen of *M. vitrata* has been discovered in southern Benin (investigated under CPP project R7247), and the fungal entomopathogen *Metarhizium anisopliae* has shown promise, but neither is likely to be implemented at farm level for some time. Current research therefore focuses mainly on botanical pesticides such as neem (*Azadirachta indica*), papaya (*Carica papaya*) and extracts of the wild herb *Hyptis suaveolens*, which are already indigenous methods of control used by some farmers.

This project built on previous development of *M. vitrata* pheromones and trap lures (R6659, R7441) to produce a pest control package combining practical pheromone traps for *M. vitrata* with botanical pesticides for control of pod borer, aphids and thrips.

## ACHIEVEMENTS

Replicated, on-station trials demonstrated that, using a variety of botanical pesticides with or without traps, yields and infestations were generally intermediate between those with the recommended conventional pesticide deltamethrin (Decis) and untreated controls. Results suggest that neem seed oil is the best botanical for controlling flower thrips and *M. vitrata*, although in practice it is difficult to obtain adequate supplies of neem leaves. Results with leaf extracts of papaya and *H. suaveolens* were less encouraging, and these cannot be recommended at present. Farmer field school (FFS) trials in 18 villages largely confirmed these findings. Through on-farm trials, the following recommendations were developed for the optimal use of traps. A minimum of five to six traps should be distributed among neighbouring cowpea fields around a village, and all cowpea fields should be sown within one week of each other. When the cumulative mean catch among all the traps reaches two moths per trap, spraying of conventional or botanical pesticides should begin within three days. Beyond this, recommendations should not be too prescriptive, and farmers should be free to decide collectively the best control agent to apply to each field – botanicals or recommended pesticide – taking account of other pests in addition to *M. vitrata*.

On-farm scaling-up trials, through FFS, were carried out with partner organisations in Benin and Ghana, but not on the scale originally intended (30+) due to unexpected budgetary constraints experienced by partner organisations. Six FFS were managed by Programa Nacional de Fortalecimento da Agricultura Familiar (PRONAF) in southern and central Benin; five by OBEPAB in northern Benin; and two each by CRI and GOAN in central Ghana (15 in total, eight of them new). Feedback from farmers in Benin indicated that the use of traps with a flexible approach to the choice of control agent enabled better integration with existing farmer practice, and better understanding and interest among farmers than previously. In Ghana, similar conclusions were reported by CRI partner staff.

*A farmer adds water to his locally produced trap to drown moths entering the trap*

A survey of several villages was carried out to assess the potential for farmer-to-farmer transmission of information about the pheromone trap and botanical pesticide technologies. This was coordinated by IITA and carried out in collaboration with other project partners. In response to a demand for practical information, two posters on the traps were produced for distribution to FFS, as well as a leaflet for FFS facilitators and extension staff giving more technical details on the traps.

It has not yet been possible to identify local commercial companies to either manufacture or supply pheromone traps or lures for *M. vitrata*. Discussions have been opened with the Ghana-based NGO TechnoServe to help identify companies to commercialise the technologies, but they were reluctant to do this in the absence of direct evidence of farmer demand; this should be provided by future work. Initial survey results indicate that a substantial proportion of farmers would be willing to pay the estimated cost of traps and lures.

During the 2004 season, traps were made by farmers as part of FFS activities. Lures were purchased from a UK supplier by IITA and distributed via project partners. Agreement has been reached that future purchases will be through the PRONAF-Benin team, with onward sale to farmers.

Following a technical development, additional work was carried out to assess the *M. vitrata* pheromone blend at five locations in Benin, Ghana, Burkina Faso and northern Nigeria. Catches with all blends at Tamale (northern Ghana), Kano (northern Nigeria) and Cotonou (southern Benin) were quite low; in Burkina Faso there were quite high catches but the best were with the single (already known) major component alone, not with the standard three-component blend previously developed at Cotonou. At Savè (central Benin) all blends did equally well. Overall there appears to be clear, but unexplained, regional variation in the optimum blend.

## FURTHER APPLICATION

A further CPP project (R8411) has been approved until January 2006 to build on work in Benin and central Ghana, and to extend it to northern Ghana and Burkina Faso. IITA is seeking further funding for a cowpea biocontrol project, which could include a component to develop effective *M. vitrata* pheromone traps for northern Nigeria, and to develop a network of light traps using pheromones for *M. vitrata* to assist with ecological studies.

# Finger millet blast in East Africa: pathogen diversity and management strategies

**R8030**

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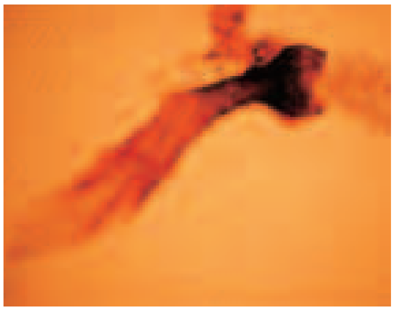
April 2001–November 2004

Although finger millet is a staple and highly nutritious food crop cultivated by millions of poor farmers in East Africa, and its high nutritional value can help sustain the health of malnourished people, it has been largely neglected by researchers. This project built on the very limited existing knowledge base to carry out studies on genetic and pathogenic diversity, and pathogen epidemiology. It has contributed greatly to developing useful diagnostic tools for pathogen monitoring and, most importantly, to more assured methods for managing blast in the field. Baseline information has been generated on East African finger millet cropping systems and constraints to production, so that interventions can be targeted with greater surety. Characterisation of the pathogen has enabled creation of a framework for identification, deployment and development of host resistance. Findings on blast epidemiology will lead to identification of disease intervention points and management strategies such as improved weed management and use of clean seed. Varieties with blast resistance, likely to be suitable for East Africa, have been identified as having potential for immediate promotion or incorporation into breeding programmes. Links to industry were also identified.

## ISSUES

Finger millet (*Eleusine coracana*) is one of the most important cereal crops in Africa and India. In the **semi-arid tropics of eastern Africa it is a major staple food for** millions of resource-poor people, and the area under production ranges from 65,000 hectares in Kenya to 500,000 in Uganda and 1 million in Ethiopia. **Finger millet** is used in East Africa primarily for malting and brewing, and for foods in the form of thin porridges. It is very nutritious, containing five vitamins, 10 amino acids and 12 mineral salts. Finger millet is considered the domain of women, and its successful cultivation enhances their status in the household and in the community. Where there is sufficient yield, women use it for brewing and also as a cash crop. Finger millet is a traditional crop and is considered important for cultural occasions such as agreement of weddings. Although not particularly drought-tolerant, finger millet is one of the hardiest crops grown in this region and the seeds have excellent keeping qualities, making it an important famine reserve food. Production has been declining due to several



Magnaporthe grisea *perithecia bearing asci and ascospores*

constraints including high labour requirements, weeds, and blast disease. Blast, caused by the fungus *Magnaporthe grisea*, is a major problem in Uganda and Kenya and is particularly severe in very wet years, in some cases causing failure of grain set and shrivelled seeds, and resulting in major yield losses. The disease was first recorded in Uganda in 1933, but very little is known of the epidemiology and diversity of the pathogen populations in this region.

## ACHIEVEMENTS

New scientific knowledge has been generated on the genetic and pathogenic diversity and mating compatibilities of East African finger millet blast populations. Information has been gathered on

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TAKAN, J.P., MUTHUMEENASKI, S., SREENIVASAPRASAD, S. *et al*. (2003) Genetic and pathogenic diversity of the finger millet pathogen in East Africa (abstract). p. 345. In: *Proceedings of the International Congress of Plant Pathology*, 2–7 February 2003, New Zealand. International Society for Plant Pathology.

TAKAN, J.P., AKELLO, B., ESELE, J.P. *et al*. (2004) Pathogen diversity and management of finger millet blast in East Africa: a summary of project activities and outputs. *International Sorghum and Millets Newsletter* 45:66–69.

blast incidence and the constraints faced in disease management, and tools and local capability for long-term pathogen monitoring have been developed.

Blast genotypes based on a collection of more than 300 characterised isolates were established. Isolates showed limited genetic diversity using polymerase chain reaction (PCR)-based markers such as amplified fragment length polymorphism and simple sequence repeats. Based on studies with other crops and fungal pathogens for which there has not been extensive selection and breeding for single-gene resistance, this limited genetic diversity in the pathogen is not surprising.

Considerable variation in pathogen aggressiveness was observed both on a particular variety and in infecting different varieties. For example, in a set of 35 blast isolates, most showed highest disease levels on finger millet variety E11, but four isolates gave the highest disease levels on variety PESE 1. Some genotypes were prevalent in both Uganda and Kenya, while others were restricted to one country.

None of the isolates tested showed clear-cut differences in compatibility, suggesting the quantitative type of resistance. Blast populations containing a DNA repeat element, 'grasshopper' (common in Asia), were found at a low level (approximately 4%), indicating recent transcontinental movement of the pathogen. Isolates causing leaf, neck and panicle blast on finger millet were genetically similar, suggesting a role for the same strains in different types of blast, thus the host resistance identified should be effective against all expressions of blast. Near-equal distribution of mating-type alleles MAT1-1 (47%) and MAT1-2 (53%) among blast populations in Uganda and Kenya was observed. Cross-compatibility assays have shown the high fertility status of these isolates, and it is important to assess the impact of this on host resistance.

Understanding of the pathogen's epidemiology, particularly the role of infected seeds and weeds in disease development, has been enhanced. Isolates of *M. grisea* from weed hosts compared with those from finger millet were generally not genetically distinct and, in most cases, belonged to the same genetic groups (except for some isolates from *Digitaria* sp.). Weed blast isolates were capable of infecting finger millet; in particular, blast isolates from wild *Eleusine* were as aggressive as some of the finger millet blast isolates, underlining the potential of weeds

*Symptoms of blast in the field*

as inoculum sources. The pathogen appears to be seedborne, with higher blast levels in susceptible finger millet varieties grown from seed lots containing higher levels of the naturally occurring pathogen. A PCR-based diagnostic test has been developed that will be useful for pathogen detection in epidemiological work and seed quality assays.

An assemblage of finger millet varieties likely to be suitable for East Africa was screened, and a range of varieties with resistance to blast identified. Such varieties have potential for immediate promotion or incorporation into breeding programmes.

## FURTHER APPLICATION

The simplicity and clear-cut nature of the new scientific knowledge that has been generated enables specific interventions to be readily identified and targeted. This makes the key outputs extremely relevant to resolving practical field problems, increasing the likelihood of their uptake and promotion to farmers.

Clear findings, for example on the suspected role of weed hosts and seedborne inoculum in the epidemiology of the disease, provide straightforward management strategies that need to be promoted. This should be facilitated by the rejuvenation of the Eastern and Central African Research on Sorghum and Millet Network (ECARSAM: www.asareca.org/ecarsam), funded by the EU through the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA).

There is also a need to disseminate the results to industry in the region. Currently in East Africa, demand for finger millet far exceeds supply, and much of the finger millet grown in Uganda is exported to Kenya (Ugandan finger millet is noted for its quality and flavour). Industry is seeking ways of increasing production and working more closely with farmers, and there is tremendous potential to enhance connectivity in the supply chain and to increase yields through widespread promotion of the outputs from this work. This provides an excellent opportunity to work directly with the farming community keen to produce millet, and also the processing industry, to promote the outputs generated as well as engaging stakeholders in the planned activities.

A regional workshop with ECARSAM, held during a short follow-on project, provided an excellent opportunity to promote the outputs and initiate connections with a wide range of stakeholders. The workshop proceedings are being prepared for distribution to regional research and development organisations, policy-makers and donors.

# Improving production in the Teso farming system through sustainable draught-animal technologies

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August 1999–March 2005

*Two members of the DAP Project team died in 2001: Joel Wange, co-leader of the project at SAARI and Nelson Olani, agronomist at SAARI.

This project worked with farmers in the Teso farming system – a semi-arid production system centred in five districts of northern Uganda – to develop appropriate animal-drawn implements, primarily for weeding but also for planting. Research activities included training of farmers in draught animal-power (DAP) weeding; planter design and testing; on-farm and on-station trials to test weeding implements and planters; and participatory assessments of weeding implements. The results have shown that DAP weeders offer a practical and effective alternative to hand-hoe weeding. For households that have access to those weeders there is an opportunity to reduce drudgery and costs of production. As hire markets develop for DAP weeding, it is likely that this will become a cheaper option than hiring manual labour. However, more effort will be needed to make weeding technology appropriate for the very poorest households, which are often female-headed and have limited access to draught animals.

## ISSUES

The Teso farming system, common in the north-eastern parts of Uganda (Kaberamaido, Katakwi, Kumi, Pallisa and Soroti districts), is characterised by pastoral and crop farming. The climate of Teso is classified as semi-arid, and rainfall is distributed over two wet seasons, March/April–May and September–November. The project concentrated on two priority crops: groundnuts, grown mostly in the first wet season; and sorghum, grown mostly in the second, shorter wet season.

The use of draught animals for land preparation (ploughing) was introduced to the Teso farming system during the colonial era (1920s) and was associated with the commercial production of cotton. The technique is therefore well established, but there has been a shortage of draught animals following civil disruption during the 1980s and 1990s. This constraint has been addressed by a number of 'oxenisation' or restocking projects, and many households are now able to open up land (by ploughing) with oxen. But this expansion of the cultivated area often leads to a labour constraint for weeding, which is undertaken by hand

*Demonstrating DAP weeding of cotton*

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O'NEILL, D.H. and AGOBE, F. (2002) The use of animal-drawn weeders in the Teso farming system in Uganda. pp. 13–20. In: *ATNESA Workshop: Modernising Agriculture Through Improved Animal Traction and Rural Transport Services,* Jinja, Uganda, 20–24 May 2002. Animal Traction Network for Eastern and Southern Africa.

OBUO, J.E.P., ORYOKOT, J., OKUNI, A. *et al*. (2001) Improving weed management in Uganda through the development of sustainable draught animal technologies. pp. 217–222. In*: Proceedings of the BCPC Conference*, Brighton, 12–15 November 2001. British Crop Protection Council, Alton, UK.

*Left to right: SAARI weeder; SG2000 weeder (from Kenya); plough minus mouldboard*

(mostly by women and children). The range of implements available for weeding and planting is limited, and the project addressed this issue by testing and evaluating with farmers, on their fields, a variety of implements likely to be appropriate to their circumstances.

Cereal crop yields (finger millet and sorghum) in the Teso farming system have stagnated at below 1500 kg/ha, despite increasing availability of high-yielding varieties. Continuous cropping of land, mainly due to power shortages which prevented the opening of new land, has led to the collapse of the traditional management practice of crop rotation, causing declining soil fertility and increasing weed pressure. A heavy build-up of mainly annual grass weeds, especially *Eleusine* and *Setaria*, occurs, and difficult perennial weeds such as *Digitaria* spp. and *Imperata cylindrica* occur in some areas. Soils in the Teso farming system are generally light, ranging from sands to sandy loams. These soil types are readily worked by animal draught equipment. However, being light, they also easily lose moisture, creating environments that allow the hardy and adapted weed species to thrive. Few farmers can afford to purchase labour for weeding as prices rise during periods of peak labour demand. This project worked with farmers to develop appropriate animal-drawn implements, primarily for weeding but also for planting.

## ACHIEVEMENTS

A survey of the weeds of Teso found the weed flora to be very diverse, with at least 85 species present (two-thirds annual broadleaves, one-sixth annual grasses). Characterisation of the different types of weeds allowed the performance and suitability of weeders to be determined in the specific context of farms in Teso.

Trials were designed to compare the use of animal-drawn weeders in line-sown crops with traditional broadcasting and hand-hoe weeding. On-station trials were conducted at Bukedea and Kaberamaido Technology Verification Centres, used by SAARI for location testing of new varieties; the on-farm trials involved nine sites, with seven farmers at each.

Two weeders were designed and made by the NARO Institutes SAARI and the Agricultural Engineering and Appropriate Technology Research Institute (AEATRI). The SG2000 weeder was imported into Uganda from Kenya. These three types of weeder were provided by the project and delivered to the nine project sites. The Cossul weeder was imported from India and was used only in on-station trials. The plough without a mouldboard (known to be used in Zimbabwe) was tested as a possible cheaper solution.

Following on-farm field trials, male and female farmers were invited to share their experience of the use of draught animal-power (DAP) weeders with the research team. A participatory rural appraisal methodology (matrix scoring) was used at the nine locations with a total of 56 male and female farmers. The efficiency of each weeder was assessed against a range of technical and ergonomic parameters. Participants assigned scores from 1–10 to each weeder for each parameter. Semi-structured interviews followed completion of the matrix to discuss and follow up issues raised by farmers.

All four DAP weeders tested on-farm performed well in terms of reducing the labour and costs required for weeding sorghum and groundnuts. Judged solely in terms of weed control, there was little or no difference between the weeders tested on-station and on-farm. However, there were significant differences in weeding efficiency, with the AEATRI weeder being least effective.

From the farmer's perspective, the plough without mouldboard, SAARI and SG2000 were the preferred weeders, while AEATRI was the least preferred.

Uptake of the most useful of these methods should lead to a reduction in the drudgery associated with hand-weeding arable crops (a task predominantly undertaken by women and children); improved school attendance during the weeding seasons; reduced costs of production, higher returns and higher incomes; and opportunities for both men and (particularly) women to redeploy labour to more productive enterprises elsewhere.

Two stakeholder workshops involving government organisations and NGOs were held in 2001 and 2002 in Enugu village, Soroti. An extension leaflet on the use of a plough without mouldboard for weeding has been drafted for distribution by SAARI.

A prototype planter has also been developed by the project.

There is a commercial opportunity for machinery manufacturers to produce a simplified SAARI weeder. This may, in the longer term, provide employment opportunities in urban and peri-urban locations.

DAP weeders are a practical and effective alternative to hand weeding, assuming that the household has access to a DAP weeder/plough at no cost. If a household owns cattle and a DAP plough, this could be adapted with little or no additional cost (although there may be an opportunity cost of not hiring out the cattle and plough). If the household does not own these resources, then the cattle and/or implement would need to be bought or hired. The introduction of DAP weeding has made women feel less oppressed, and men have become involved in this task as it is mechanised. A great reduction in drudgery is reported, along with improved food security and higher incomes. Women are now able to pursue more rewarding activities and are experiencing a better quality of life. Children are no longer withdrawn from school during the weeding seasons. Farmer-to-farmer extension may be one of the more effective means of achieving rapid adoption of technology, as most farmers in rural Uganda have little, if any, contact with formal extension services. It is anticipated that, in the longer term, even the poorest of economically active households will benefit from mechanisation as hire markets develop for DAP services (weeding, groundnut lifting and potato ridging).

## FURTHER APPLICATION

The project was extended beyond March 2005 to promote weeding and planting technology to more Teso farmers via training of trainers (extension workers) to ensure sustainability. Two additional DAP technologies were promoted: the use of a plough for ridging/ weeding sweet potatoes and lifting groundnuts. Both have been particularly well received by farmers, and widely adopted. The mechanisation of potato ridging reduces labour costs from USh120,000 to USh24,000 per hectare.

Farmer-to-farmer extension was chosen as the most appropriate means of encouraging more farmers to use their draught animals for weeding. Extension materials (a manual for trainers and posters for farmers) were produced and distributed. Expert farmers in the nine original project locations were supported (but not paid) to train their friends and neighbours, and more than 1100 farmers have been trained in this way. Staff of NGOs working in Teso are being trained to ensure that DAP weeding extension continues. Over 800 trainers (NGO extension workers) and 1200 of their client farmers have been trained in the past two years.

*Making ridges for sweet potatoes*

Links have been established with a private-sector machinery manufacturer (SAIMMCO) in Soroti town to develop the fabrication of DAP weeders for future sustainable supply of equipment in the Teso farming system. Although participating farmers identified the SAARI weeder as their preferred tool, the design was inefficient from a manufacturing point of view. Discussions with farmers, scientists and manufacturers resulted in design concept changes and the production of a second-generation prototype which incorporated those aspects required by farmers, but reduced manufacturing costs (and retail price). SAIMMCO has sold over 250 of these weeder units to date.

The project also assisted the manufacturer with the design and printing of promotional literature. Leaflets were distributed widely among the farming community, especially during field days and demonstrations where the weeder (and other agricultural equipment) was demonstrated. For the manufacturer to be successful sales must be maximised, and to aid this a system of market agents has been organised. Seven agents, all based in rural areas, are seeking markets for weeders, communicating orders to the manufacturer in return for a small commission.

A series of field days (agricultural shows) were held during rainy seasons in 2004 and 2005. These included live demonstrations of DAP weeding, ridging and weeding of sweet potatoes, line planting and other equipment, along with displays by the manufacturer and artisans. Local leaders and farmers were invited, with local and national media (radio and newspapers), with the objective of popularising the use of DAP. These field days also provide an opportunity for dialogue between manufactures and farmers and other organisations (NGOs and extension workers).

# Groundnut rosette disease management

**R7445**

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July 1999–June 2002

Seee R6811, *Perspectives on Pests 1996–2000*, p. 27

Groundnuts are a key crop in eastern Uganda, grown for both food and income. The major factor limiting production is groundnut rosette disease, a virus disease transmitted by aphids. This project built on previous CPP epidemiological research in Malawi which identified new sources of resistance to aphids and to rosette disease. Screening methodologies were developed to enhance the efficiency of groundnut improvement programmes. Working closely with researchers, agricultural extension agents, NGOs and farmers, the project's ultimate aim was to to develop sustainable management strategies for groundnut rosette disease, based primarily on the use of improved groundnut varieties with durable resistance to pests and diseases. The availability of new, short-duration, disease-resistant groundnut varieties will assist a substantial number of smallholder farmers to increase their income.

## ISSUES

A needs assessment commissioned by DFID in 1998 recognised the importance of groundnuts for both subsistence and income generation, and identified groundnut rosette disease and aphids as serious constraints to production. This project addressed these problems, primarily by developing and promoting groundnut varieties that would combine pest and disease resistance with other key characteristics that are demanded by farmers.

## ACHIEVEMENTS

A large-scale household survey was conducted in three districts in the Teso farming system of north-eastern Uganda, and a database was compiled of social and economic data related to groundnut production, including groundnut rosette disease. The survey found that farmers consider several traits when selecting a groundnut variety, including drought resistance, duration, quality characteristics, yield, and pest and disease resistance. Rosette

*Rosette-resistant plants (left) improve groundnut yields*

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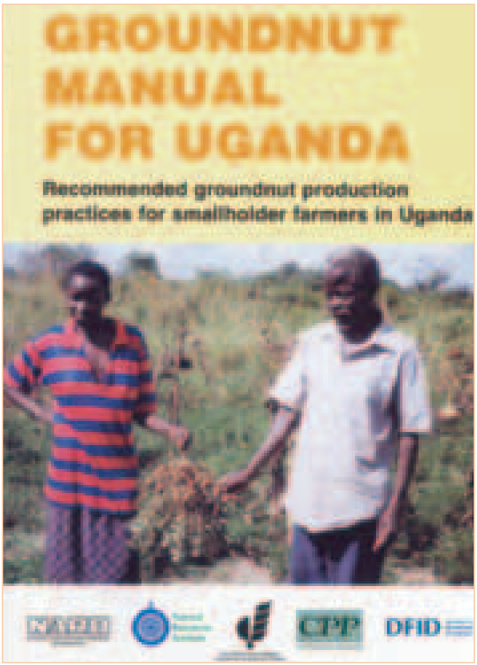
*Traditional drying of groundnuts (Soroti)*

disease was known by the local name of *atikuba* and the range of available varieties and their qualities were collated. Specific information was fed back into the breeding programme at SAARI and used to refine the criteria used for assessing new breeding lines. Other important survey findings related to how farmers obtain information on farming practices. The information obtained – that very different approaches are needed to reach different categories of farmer – was used to guide the project's dissemination strategy.

The Ugandan Seed Committee approved two high-yielding, short-duration, rosette-resistant groundnut varieties for release within three years of the project's starting in March 2002. The seed of one variety, Serenut 4T (ICG 12991), is tan-coloured and vector-resistant whereas that of Serenut 3R (ICGV-SM 93530) is red and resistant to groundnut rosette virus, so farmers have a wider choice to meet their own and local market requirements. The short duration of the varieties will allow farmers to grow two crops of groundnut a year and thus to enhance their income potential significantly.

These varieties are expected to emulate the success of Serenut 2, released in 1999. Evaluation of the varieties together with other candidate lines in large numbers of on-farm trials has demonstrated that farmers appreciate their qualities. Serenut 4T was particularly favoured because of the large number of seeds it produces and because it resembles a popular local variety (Erudurudu) in appearance. Complementary




research led to the development of a practical field-based method for evaluating vector resistance in groundnut.

In addition to the field work in Uganda, a PhD programme investigated the mechanisms of resistance in a range of groundnut genotypes. Of particular interest was a study of Serenut 4T (ICG 12991), which confirmed that it was resistant to the aphid vector through the mechanisms of non-preference and antibiosis. Detailed feeding studies revealed that virus transmission by the aphid vector might be inhibited through the collapse and death of plant cells at the feeding site.

A second PhD programme identified molecular markers linked to the vector resistance gene in ICG 12991, and a basic genetic linkage map for groundnut, the first of its type, was developed.

A *Groundnut Manual for Uganda* (www.cpp.uk.com/outputs.asp) was compiled and 1000 copies distributed to agricultural extension agents and NGO staff and used as a key reference by farmer field schools and extension providers.

## FURTHER APPLICATION

Considerable attention was devoted by the project to enhancing the institutional capacity within Uganda to help ensure the gains made from this research will be sustainable. Strong links were forged between SAARI and ICRISAT in Malawi, and a self-sustaining system of groundnut seed multiplication and distribution has been established. A key feature is the role played by NGOs in delivering seed to those farmers who stand to benefit most from growing it. The multiplication rate of groundnut seed is slow and does not attract interest from private seed companies. One of the project collaborators, Appropriate Technology-Uganda (AT-Uganda), has continued this work through a community-based dissemination approach (farmer-to-farmer) transfer of new rosette-resistant groundnut varieties, (R8105, see page 59).

Groundnut rosette disease is a serious constraint to groundnut production throughout West Africa, and a similar approach to the evaluation and promotion of rosette-resistant varieties using the lessons learnt from this project would benefit that region.

# Farmer-led multiplication of rosette-resistant groundnut varieties for eastern Uganda

**R8105**

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February 2002–March 2005

Legume seed availability is a major constraint on crop diversification in many African farming systems. This project has shown how, through careful and innovative use of participatory methods, it is possible to produce high-quality seed and get it widely distributed among the population, including the poorest. Groundnut production has been declining due to groundnut rosette disease. Poor farmers cannot afford chemicals to control the aphid vector of this virus disease, yet the risk of failure caused by the disease is very high. This project focused on enabling poor farmers to reverse the decline in production through promotion of farmer-led multiplication of rosette-resistant groundnut varieties under the supervision of local leaders, to give poor farmers increased access to new resistant varieties. Extension staff, local leaders and farmers have been trained in groundnut production, multiplication and storage, and foundation seed for new rosette-resistant varieties has been obtained and multiplied by farmer group members. Multipliers have returned twice the amount of planting material received, for redistribution and further multiplication. Managing the process of collection, redistribution and monitoring of seed multiplication has been handed over to local leadership.

## ISSUES

This farmer-led multiplication project was implemented in five districts in eastern Uganda (Kumi, Pallisa, Tororo, Mbale and Sironko) and covered 16 sub-counties, the same area as AT Uganda's LIFE Project focusing on improving rural livelihoods by enhancing food and income security.

Poor households in the region face two serious problems in groundnut production: inadequate seed supplies, and lack of cash to buy chemicals to control the aphid vector of groundnut rosette disease. Through farmer-led multiplication and use of disease- and vector-resistant varieties, both constraints can be addressed. New rosette-resistant varieties of groundnuts (Serenuts 2, 3R and 4T) had been released, but seed availability was limiting, especially for the rural poor. A previous project (R7445, page 51) had already extensively tested the early maturing, disease-resistant varieties (Serenuts 3R and 4T) multiplied in on-farm trials, involving AT Uganda as a stakeholder.

## ACHIEVEMENTS

Farmer-led verification and multiplication of improved crop varieties was used to provide poor farmers with access to the improved varieties, practices, knowledge and information they need to increase crop productivity. A publication on groundnut production produced by project R7445 was used as a training resource. This project was based on involving the target beneficiaries in activities to ensure their participation and ownership of the process for long-term sustainability and benefit. The approach emphasised the participation of farmers in planning, implementation,

*Groundnut rosette symptoms*

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NAMISI, S., LAKER-OJOK, R. and SMIT, J. (2004) *Impact Assessment Report for Farmer-led Groundnut Multiplication in Uganda*. Appropriate Technology-Uganda (AT-Uganda) Ltd.

TINO, G. (2004) Farmer-led multiplication of rosette-resistant groundnut varieties. *Uganda Journal of Agricultural Sciences* 9: 578–582.

*Safia Aseku, groundnut farmer, with her pregnant heifer purchased with the profits of her groundnut crop, Bukedea County, Uganda*

monitoring and evaluation of activities.

Farmers' groups participated in the preparation of seed distribution plans, and established regulations to ensure seed was not lost, to avoid breaking the distribution chain. Local leadership structures were put in place at group level (production committees, PCs) and at parish level (parish development committees, PDCs), with defined roles to ensure planned activities were completed. Seed was given to individuals in groups as loan seed, to be repaid with seed interest, so that it was multiplied until all target households had access to it. Distribution and repayment of the loaned seed was public to ensure accountability, and groups exerted peer pressure to ensure seed was repaid.

An impact survey conducted in September 2004 estimated that 17,154 people had received seed of improved groundnut varieties Serenuts 2, 3R and 4T (see page 57) – almost double the projected target of 9000 recipients. Of these, 3634 people received seed directly from the project, 5910 purchased seed from beneficiaries, and 7610 received seed through gifts or as payments in kind. The survey indicated that enough seed to plant 3275 hectares had been given out, of which 1092 came direct from the project, and 2183 resulted from seed sales and gifts. Estimated production from 2004 alone was sufficient to plant 4725 hectares if the whole crop was committed to seed.

In addition, the availability of seed of the introduced varieties has increased substantially and large quantities are being sold, enabling other non-participating farmers to benefit and further disseminating the new varieties. Use of home-saved seed and purchase from other farmers is the most reliable way that groundnut farmers ensure seed availability, and is being widely practised by beneficiary farmers. Fifty-two per cent of the project beneficiaries are women.

The PDCs and PCs were trained in seed production and the training was reinforced through publication of simple production guides. Those individuals then went on to train other beneficiaries. A total of 960 community leaders (PDCs and PCs) and more than 6000 farmers have been trained in groundnut production, storage and multiplication.

Redistribution of the varieties is continually increasing under the guidance of local leadership, but at a somewhat less than expected repayment rate, and lessons are continually being learned about how to improve the system to ensure a good rate of multiplication.

This project has greatly increased access to rosette-resistant varieties and ensured that the seed reaches the hands of poor farmers. It has also helped test a novel approach that can be effectively replicated by others to successfully promote dissemination of research outputs.

## FURTHER APPLICATION

As a result of the strong foundation laid by this project, AT-Uganda is now well placed to expand this novel approach to new communities and facilitate market links for poor farmers. Planned activities include:

- selection and training in new sub-counties, parishes and groups
- establishing PDCs and PCs in the new sub-counties
- setting up marketing committees; market promotion
- establishing community stores for a groundnut assembly.

# Wild rice management strategies for the lowlands of southern Tanzania

**R8198**

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October 2002–March 2005

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Rice is a vital cereal crop in Tanzania, and the majority of rice farmers depend on it both for food and as a cash crop. This project aimed to develop and promote strategies and extension materials for the management of highly competitive wild rice weed species in Tanzania. Farmer–research groups undertook demonstration trials on wild rice-infested farms in three districts. Farmers identified the use of glyphosate before planting as the best option for managing these weeds. For in-crop weed control, post-emergence application of 2,4-D was favoured to reduce labour inputs. Yields in glyphosate-treated plots have more than doubled compared with farmers' previous practices. The sustainability of the production system has been enhanced as farmers become aware that application of glyphosate to perennial wild rice prior to seeding rice reduces subsequent in-crop weeding time by 50%. Extension materials were produced to provide farmers with the knowledge to use herbicides safely and effectively. Results from this project have provided district council extension managers with an opportunity to consider how to incorporate wild rice management issues into future extension programmes.

## ISSUES

Rice is the second most important cereal crop in Tanzania after maize, and the majority of rice farmers depend on it both for food and as a cash crop. Weeds, including highly competitive annual and perennial wild rice species (*Oryza punctata* and *Oryza longistaminata*, respectively), are one of the major constraints to rice production on lowlands in central and southern Tanzania. Wild rice is a cause of very low yields on large-scale farms, and is a major problem confronting small-scale farmers. Wild rices are the only known alternative hosts for African rice gall midge, and are important hosts for rice yellow mottle virus. Both are important pests of the rice crop both in Tanzania and more widely in West Africa.

*Using herbicide before planting results in a clean rice crop in Kyela; unsprayed area in background*

In Tanzania, lowland rice production is undertaken both on large, mechanised parastatal farms, and by smallholders who cultivate either with a hired tractor, by hand or by ox-drawn plough. *Oryza longistaminata* occurs widely in Kyela and Kilombero districts on rainfed floodplains farmed by smallholders. Control is by cultivation, removal of rhizomes by hand, and hand-weeding. Before this project, little herbicide was used, and some of those that were applied (such as picloram and paraquat) are not intended specifically for weed control in rice.

*Oryza punctata* thrives on irrigation schemes under a system of direct seeding of rice with poor water management, and this has contributed to the collapse of some large commercial operations. Due to their low profitability, substantial portions of these enterprises have subsequently been handed over to smallholder farmers, but the problems with wild rice persist under current agronomic practices.

*Removing wild rice rhizomes before planting in Kyela (above and right)*

Annual and perennial wild rice weed species are difficult to control because they are similar in appearance to cultivated rice in the vegetative stage, and compete vigorously with the crop. A previous CPP project (R7345) studied control methods for annual wild rice in Ghana and Mali. Building on that work, this project aimed to evaluate the use of glyphosate as a component of improved rice management with farmer groups for *O. longistaminata* control on two floodplain areas, and against *O. punctata* at Dhakawa and Ruvu.

*Field day participants, Kyela*

## ACHIEVEMENTS

Seven farmer–research groups, with membership from 128 households, undertook demonstration trials on 32 farms infested with wild rice. Participatory evaluation during field days and sensitisation workshops involved more than 230 rice producers from seven villages within the project areas. Farmers identified the use of glyphosate before planting at the rate of 3 l/ha for the control of annual wild rice (on irrigated land) and 4 l/ha for the control of perennial wild rice (on rainfed fields) as the best options for management of these weeds. Post-emergence application of 2,4-D at 21 days after germination was favoured to reduce labour inputs for in-crop weed control.

Partial budget analysis undertaken with growers, district agricultural extension staff, village chairmen

and ward executive officers demonstrated the benefits of improving wild rice management. When glyphosate was used, income from rice production could be increased from a cost–benefit ratio of <1 (0.64) to 2.94 for farmers in Kyela; 3.25 for Dakawa; and 4.93 for Ruvu. A significant increase in yield of more than 4 t/ha over the control has been achieved using glyphosate before planting and 2,4-D at 21 days after crop emergence. This positive result has been an added incentive to technology adoption.

In addition to the experimental fields, group members from Michenga and Lumemo villages in Kilombero set up demonstration plots on their own fields to enable other farmers in the district to copy the technology they have acquired. Due to the involvement of different rice-production stakeholders in seminars and field days, and following the Deputy Minister for Agriculture's visit to one of the trial sites, the supply of glyphosate has increased. More than 3500 litres of glyphosate were purchased between November 2004 and February 2005 in areas where the project has been operating, compared with less than 500 litres in 2003. To support promotion, the project prepared a leaflet and poster (3000 and 1500 copies, respectively) and distributed them to extension teams and farmers.

*Farmers and pesticide dealers need better training – rice damaged by an unsuitable herbicide that was sold on Kyela market for use in rice*

Rice yields in glyphosate-treated plots have more than doubled those achieved by farmers' usual practices, and income from rice production has increased substantially. The sustainability of the production system has been enhanced as farmers have realised that application of glyphosate to *O. longistaminata* regrowth or *O. punctata* seedlings prior to seeding rice allows wild rice-infested land to be cultivated profitably. This previously abandoned land includes areas with the deepest water and highest soil fertility, with the highest potential for rice production. The combination of wild rice suppression by glyphosate and in-crop weed control with 2,4-D reduces subsequent in-crop hand-weeding time by 50%, a saving in labour welcomed by growers.

## FURTHER APPLICATION

The areas targeted by this study are mostly sown to low-yielding, traditional rice cultivars, and little fertiliser is used. Growers participating in the project, particularly in Dhawawa and Ruvu irrigation schemes in Ifakara District, are now interested in intensifying cultivation at high-potential sites. This includes growing a newly released, high-yielding cultivar of aromatic rice (TXD 306 or SARO 5) which is not sufficiently competitive to perform on infested fields in the absence of wild rice control. A one-year extension to the project (R8477) will include demonstrations of combining the new cultivar with use of glyphosate, 2,4-D and fertiliser. These demonstration activities will be undertaken through farmer groups in collaboration with the district extension services.

# Green manure for enhancing upland rice productivity on *Striga*-infested fields in Tanzania

**R8194**

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September 2002–March 2005

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MBWAGA, A.M. and RICHES, C.R. (2004) Achievements in 2004 Season on promotion of green manure to increase soil fertility and control Striga in Kyela and Matombo districts. ARI-Ilonga, Kilosa, Tanzania. 46 pp.

ARI-ILONGA (2004) *Kudhibiti Viduha kwa kurutubisha udongo kutumia Marejea*. ARI-Ilonga, Kilosa, Tanzania (poster in Kiswahili).

ARI-ILONGA (2004) *Mbegu bora ya maharage*. ARI-Ilonga, Kilosa, Tanzania (poster in Kiswahili).

Yields of upland rice have been declining in Tanzania, mainly due to an increase in the parasitic witchweed *Striga asiatica*. Use of a legume/rice rotation, rather than continuous rice cultivation, has been evaluated and shown to have potential for adoption over large areas of Tanzania, not only where *Striga* is a problem, but also in areas with poor soil fertility. This is especially useful for resource-poor farmers who cannot access or afford inorganic fertilisers. Farmers in participating villages have begun to adopt the use of green manure on a large scale, and *Striga* infestation has decreased. Yields of rice following the green manure *Crotalaria* increased consistently by a factor of two, compared with those of rice following rice – and by a factor of six in a few cases. The project has demonstrated the value of using a range of partnerships, including research, extension and schools, to promote knowledge of improved agricultural practices. Extension materials have been produced that can be used elsewhere in the country to support promotion of cereal/legume rotations that improve farm productivity and incomes.

## ISSUES

Rice is the second most important cereal crop in Tanzania, and demand from urban centres is increasing annually. Under continuous cultivation, rice yields in the rainfed uplands have been declining in recent years due to falling soil fertility and an associated increase in infestation by the parasitic witchweed *Striga asiatica*. In southern and eastern Tanzania, farmers have witnessed declining harvests, from more than 3 tonnes to little more than 400 kg/ha in living memory. Work carried out with farmer groups in Kyela since 1996 (CPP project R7564) demonstrated that up to 60% reduction in *Striga* and 45% increase in rice yield could be achieved by applying urea fertiliser on upland rice fields. Although some farmers in project locations may have used fertiliser in the past, few could afford the increased costs following the removal of subsidies under national Economic Structural Adjustment Programmes. Another approach to managing *Striga* that boosts soil health is therefore needed.

Striga asiatica *stunts rice growth*

The legume green manure *Crotalaria ochroleuca* (*Marejea* in Kiswahili) has been grown for many years at St Benedict's Abbey, Peramiho, southern Tanzania, to maintain the fertility of organic gardens. When broadcast as a sole crop, growth is vigorous so that weeds are suppressed, providing a clean entry for the subsequent crop. Previous attempts to popularise the use of *Crotalaria* met with little success, due to a prescriptive top-down approach, with extension officers providing

*Vice-chairman of village next to his* Crotalaria

little knowledge to farmers on how to incorporate green manure into their systems, or on its economic benefits. This project reintroduced the concept of using both *Crotalaria* and the grain legume pigeonpea for soil fertility enhancement and *Striga* management, through a programme of village-level seminars and demonstrations, a process that subsequently became farmer-driven.

## ACHIEVEMENTS

The project undertook promotional activities in two districts of Tanzania – Kyela District in the Southern Highlands Zone and Matombo Division in the Ulugulu Mountains of Morogoro Rural District in the Eastern Zone. Shifting cultivation is still commonly practised in Matombo although fallow periods are generally much reduced, while in Kyela land is cultivated continuously.

Farmer research groups were formed in eight villages in Kyela, where rice is the major food and cash crop; and five in Matombo, where both rice and maize yields have declined due to *Striga* infestation. Participants carried out a context analysis, selected sites and established demonstrations, which included plots of *Crotalaria*/rice and pigeonpea/rice rotations compared with continuous rice. These groups undertook 117 and 122 demonstrations of the legume–rice rotations in Kyela and Matombo, respectively.

Farmers assessed rice and maize planted following legumes to be more vigorous than continuously grown cereals. Only one light weeding was needed in rice after *Crotalaria*, compared with two or three in continuous rice, and *Striga* infestation was reduced by 50% by *Crotalaria*. Rice yield following *Crotalaria* increased more than 90% on average compared with continuous rice, with many farmers achieving more than 100% greater harvests. Rice yields after pigeonpea increased by 20%. Consequently, there has been a steady increase in the number of farmers adopting rice–legume rotation through farmer-to-farmer extension, and demand for *Crotalaria* seed is outstripping supply. Kyela farmers have sold 400 kg of seed to neighbours, to Matombo and to farmers participating in project R8215 (page 85) in Muheza District of northern Tanzania.

A total of 21 village primary schools have included knowledge on the biology and management of *Striga* in the agricultural school science curriculum. Schools demonstrated the value of *Crotalaria* and pigeonpea to increase soil fertility and control of *Striga* using songs, plays, poems and traditional dances, and by setting up demonstration plots at their schools. Publications produced include a leaflet on the use of *Crotalaria* (2000 copies) distributed to extension staff, farmers and schools, and a poster on *Crotalaria* (500 copies) distributed to schools, hospitals, churches/mosques and extension offices. A video has been produced documenting the use of green manure to improve soil fertility and to reduce the impact of *Striga* on the rice crop.

## FURTHER APPLICATION

Promotion work continued during 2005 with increased backing from ward-level education and agricultural extension staff. The video tape on the use of *Crotalaria* was used during training of extension staff and lead farmers. Another video, documenting the school pathway, will be aired on Tanzania Television. A *Striga* management training manual was also produced and distributed to extension officers, primary school teachers and NGOs. The project approach and training materials were presented to district council agricultural extension managers and NGOs from other districts of southern Tanzania where *Striga* and yield decline in upland rice are major problems.

*Primary school children perform drama about how to control Striga*

Various initiatives, including the Millennium Project Task Force on Hunger, are now promoting a ‘21st century green revolution’ for Africa. The techniques and communication materials developed with farmers in two major rice-growing regions of Tanzania can make a contribution to this green revolution. Low soil nitrogen can be replenished by green manures that fix atmospheric nitrogen in the soil and manage the pervasive witchweeds, which reduce yields. If combined with low-cost water-harvesting techniques, such green manures can provide a highly reliable package of soil, weed control and water interventions.

# Developing crop protection research promotional strategies for semi-arid East Africa

**R8349**

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November 200–March 2005

Recent policy research has identified the food crop sector as offering the largest potential return to investment in research and development in Africa, in the medium to long term. In the context of generating returns from existing research investments, a major challenge identified by this project was how to empower local agricultural service providers to access and process existing crop protection information and products, in order to meet farmers' needs. The project used information and products generated through CPP and other research with potential to bolster the household food security and incomes of smallholders in semi-arid East Africa. The aim was to improve access to crop protection knowledge through trying out various approaches and tools within pilot learning sites. This was achieved by an action-learning approach which ultimately led to the identification of better promotional and communication strategies. With a view to sustainability, and in the context of the decentralisation and reform of agricultural service provision, the project built on collaboration with existing organisations, institutional mechanisms and initiatives.

## ISSUES

People living in semi-arid sub-Saharan Africa are among the most resource-poor (most fall below the poverty data line) and are most challenged by their environment. A  major feature of this environment is its relatively low and unreliable rainfall. The vast majority of households depend on crop production (directly or indirectly) as their main livelihood source, although through choice or necessity pursuing diverse livelihood strategies. Most of the crops grown are vital to food security but are of low market value. Infrastructure is relatively weak, and this contributes to the generally low level of private sector service provision. While crop protection issues can be major production constraints, the financial returns to improvements in crop protection are more limited and risks are greater than for higher-value crops in higher potential areas with good market access. Public extension (at times working with local NGOs) is still the main service provider but, for a variety of reasons, traditionally has struggled with its limited personnel to provide a quality service to widely dispersed populations.

A wide range of pests – notably stem borers, *Striga*, smut and leaf diseases in cereals, insect pests in legumes and vegetables, pests in

*A farmer being interviewed by local radio*

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RICHES, C. and LAMBOLL, R. (2003) Learning how to learn together: agricultural communication in Central Tanzania. *Tropical Agriculture Association Newsletter* 224.

SUTHERLAND, A.J., KATUNZI, A., KAVOI, J., LAMBOLL, R., OGECHA, J. and RICHES, C. (2005) Developing Crop Protection Promotional Strategies for Semi-Arid East Africa. *Agricultural Research and Extension Network Newsletter* No. 51. Overseas Development Institute, London.

*Discussing* Striga*-tolerant sorghum varieties with a farmer in the field*

cotton and pests in stored grain – further constrain stable levels of production and income. Three projects focusing on sorghum (R7518, R7572, R7504) were followed by stakeholder workshops in Kenya and Tanzania that identified a demand for accessible and appropriate dissemination of the project findings.

## ACHIEVEMENTS

Three inter-agency teams were formed to facilitate comparison of experiences and organisational lesson learning. The central Tanzania team was coordinated by an NGO, INADES-Formation Tanzania; and other stakeholders involved included public extension at various levels, farmers and public research. The eastern and south-western Kenya teams were coordinated by two KARI centres (Katumani and Kisii), working with public extension at various levels, NGO extension providers and farmers (including 'para-extensionists' – volunteers selected by the local community trained in crop protection).

Mechanisms were reviewed for updating demand and gathering feedback on the performance of crop protection research products. In Kenya the focus was on the advisory committees established in 1994 under a joint memorandum of understanding between research and extension. These were found to be reasonably effective mechanisms for updating demand about major issues, but had provided very limited feedback on technology performance, and had failed to attract consistent representation of farmers, NGOs and agribusiness. Measures to improve the performance of these committees were identified. In Central Tanzania, in the context of a previously centrally driven agricultural information and extension system, the project team piloted implementation of a decentralised extension service model as part of ongoing political decentralisation. This was done to set the baseline against which to assess the early stages of implementing a decentralised extension service model as part of ongoing political decentralisation. The development of a participatory monitoring and evaluation system as part of zonal and district communication strategies was identified as a potentially key intervention for improving demand and feedback mechanisms at various levels. The project facilitated the design of participatory monitoring and evaluation, linking farmers with the zonal agricultural communication office through district council extension services.

At all three sites (one in Tanzania, two in Kenya) the use of participatory learning approaches (collaborative on-farm trials, farmer field schools, group-based demonstrations) to adapt and disseminate crop protection information was found to stimulate demand for the new crop protection research products. Such approaches were also effective in obtaining feedback when combined with training and capacity building in crop protection.

The project design drew on stakeholders' (extension providers, farmers, researchers) expressed views that relevant crop protection information was difficult to access. This view challenged a simplistic model of 'demand-driven' research and extension services. As an extensionist commented at a stakeholder workshop: "You [researchers] need to stimulate demand – how will we know what is available if we are not informed, and how will we know how to use it if we are not empowered?"

Farmers' and extension providers' actual and preferred sources of crop protection information were explored. Farmers' main sources cited were other farmers, public extension, and (in some locations) para-extension. Farmers saw information from public extension, stockists and newspapers as more reliable than the alternatives. Both farmers and extension service providers preferred face-to-face interactive information sources such as field schools, demonstrations and training sessions.

Although preferred, these sources of information are currently accessible to only a minority of the extension providers and farming populations in semi-arid areas. Initiatives identified through the project to improve local access and stimulate demand for crop protection information within a decentralised setting included a catalogue of crop protection products for drier areas of south-western Kenya; a training-of-trainers crop protection manual for semi-arid eastern Kenya; Kiswahili crop protection posters; and leaflets and radio broadcasts for central Tanzania. In central Tanzania the development of zonal and district communication strategies provided a framework for exploring how district extension staff and the Zonal Communication Office access information and ideas for improvement. A review of the performance of these strategies indicated that factors encouraging dynamic information-seeking and exchange need to be explored further if a pluralistic and decentralised extension model is to be effective.

Quality assurance in relation to the development of training information and products remains an issue. Preliminary feedback on the quality of locally produced information products is very encouraging, and the process of producing these materials locally has been empowering for the research and extension staff involved.

At each site a range of pathways and methods was tried with the aim of evaluating their strengths, weaknesses and (where possible) cost-effectiveness. The farmers targeted were the regular service users of the various pathways piloted. The majority are smallholders living in semi-arid areas relying on ox-drawn or hand-hoe cultivation, producing for their own consumption, and in some cases marketing their surplus. However, in areas where the extension approach has been enterprise-oriented, there has been a focus on producer groups with an interest in cash enterprises such as tomatoes and onions. In each case the technologies disseminated were based on an analysis of potential demand and opportunity, following consultation at various levels.

In Kenya the focus was on comparing public extension and NGO para-extension pathways using 'best-bet' face-to-face extension methods such as farmer field schools, demonstrations, *barazas* (public gatherings convened by the local chief), teaching of existing groups, and farmer-to-farmer extension.

In Tanzania a range of communication tools were used in the implementation of the zonal and district communication strategies. The strengths, weaknesses and ways of improving these various tools were assessed with farmers. While all the face-to-face methods piloted were effective in terms of farmer learning and application of knowledge, their costs differ. The most interactive methods seem most effective for more complex types of information. Based on the first season of monitoring, it was found that the use of para-extensionists is cost-effective in terms of reaching and training farmers who would otherwise not be reached.

In the early stages, many of the stakeholders did not appreciate the centrality of monitoring and evaluation to the lesson-learning process. It has taken all involved time to fully appreciate what is involved in implementing this effectively, and to understand that developing participatory monitoring and evaluation at community level is very ambitious in a project of short duration. Much of the focus on lesson learning (as distinct from technology dissemination) has been at the 'meso' (district and region) rather than community level. This has been through stakeholder review workshops involving sharing experiences, participatory documentation and analysis. The results indicate that each stakeholder group will identify different types of lesson, depending on their interest and perspective – raising the question 'who is lesson learning for?'

Through visits to national offices and production of short fliers and progress reports, dialogue was initiated with important national programme initiatives in agriculture: the Kenya Agricultural Productivity Project (KAPP) in Kenya; and the Agricultural Sector Development Programme (ASDP) in Tanzania. Areas were identified where findings from this project could usefully inform these larger agricultural service reform programmes. For example, KAPP plans to assess various extension approaches in order to inform extension reform, and is looking to re-orient research towards achieving greater developmental impact. In Tanzania, ASDP programme management supported the opportunity to pilot agricultural communication approaches that would be compatible with the emerging institutional arrangements and farmer focus of its component projects. The ASDP coordinator encouraged the project team to work through the Central Zone district councils.

## FURTHER APPLICATION

Project activities were extended to January 2006 under project R8428. This will provide time to improve the quality of lesson learning around promotional and communication strategies; strengthen links with policy players; and deepen learning about undertaking monitoring and evaluation. It is expected that the participating agencies in Kenya and Tanzania will use the lessons learned from both phases to scale out effective communication in semi-arid areas beyond 2006. Action research will need to continue, and some of the issues thrown up by this project will require further in-depth research to produce the type of evidence needed to underpin proposed policy changes. This includes further research into:

- practical methodologies for assessing the cost-effectiveness of alternative extension and communication approaches and methods
- developing a workable model for participatory monitoring and evaluation in the context of decentralised pluralistic extension services
- partnership models for accelerating the rate of crop protection-related technology development and adaptation for semi-arid smallholder systems
- knowledge management in the context of reform towards pluralistic research and extension providers, including public–private partnerships.

# Management strategies for maize grey leaf spot in Kenya and Zimbabwe

**R7566**

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April 2000–March 2003

Small-scale maize farmers in Kenya and Zimbabwe experience significant yield losses (up to 40%) as a result of maize grey leaf spot (GLS), caused by the fungus *Cercospora zeae-maydis*. The epidemiology of the pathogens(s) was studied in order to develop and promote appropriate improved management strategies. This project has quantified the distribution and importance of GLS. The knowledge generated, together with existing literature, has been used to design, develop and promote an IPM strategy for the disease that has a high probability of being effective and adopted by small-scale farmers. The strategy is based on the use of cultural methods for the removal of crop debris, soil fertility, and recommendations concerning host resistance. The project has used a variety of promotional means to raise awareness of GLS and its management among farmers and extension staff.

## ISSUES

Grey leaf spot (GLS), caused by *Cercospora zeae-maydis* and, to a lesser extent, *Cercospora sorghi* var. *maydis,* is recognised as a major constraint to global maize production. In Africa, yield losses ranging between 30 and 60% have been reported, and the disease is considered to pose a serious threat to food security. GLS was first reported in Kenya and Zimbabwe during the 1995 growing season, when small-scale maize farmers experienced significant yield losses. At that time most of the maize varieties being grown were highly susceptible to the disease. Small-scale maize farmers have continued to experience considerable yield losses, particularly in GLS 'hot spots', and in some areas have been relying heavily on the use of expensive fungicides to control the disease. Following the initial outbreaks of GLS in Africa, breeding programmes were undertaken by the maize seed companies, and GLS-tolerant varieties first appeared on the market in southern Africa in 1997. Initially these were expensive, lower-yielding, late-maturing varieties inappropriate for small-scale maize farmers. In the past two years this situation has changed with the increasing availability of affordable, higher-yielding, early-maturing varieties. Nevertheless, there continues to be a reluctance among some small-scale maize farmers to switch to GLS-tolerant varieties. This project looked at the use of early-maturing varieties and the availability of host resistance – potentially the most cost-effective method for managing

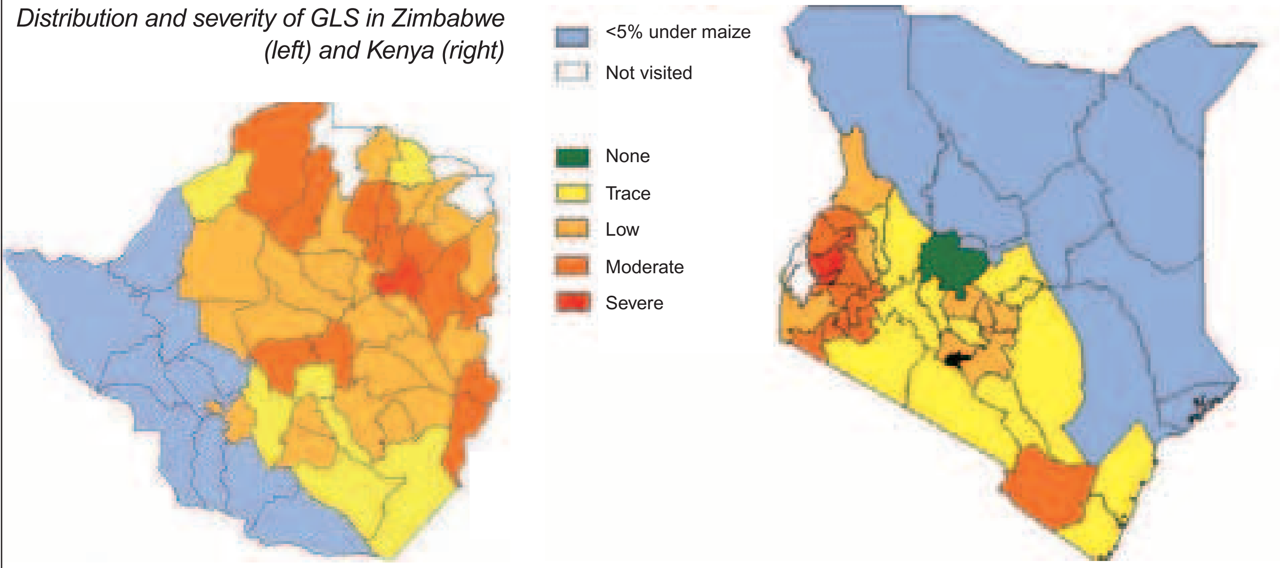
*Maize grey leaf spot can cause severe symptoms*

## SELECTED PUBLICATIONS

CABI ARC (2002) Socio-economic survey of maize grey leaf spot on small-scale maize farms in Kenya and Zimbabwe: farmer perceptions and economic analysis. CAB International Africa Regional Centre, Nairobi, Kenya.

CABI ARC (2003) Options for managing maize grey leaf spot: a leaflet for small-scale farmers in Kenya (in Kiswahili, Shona and English versions). CAB International Africa Regional Centre and Kenya Agricultural Research Institute, Nairobi, Kenya.

*Distribution and severity of GLS in Zimbabwe (left) and Kenya (right)*



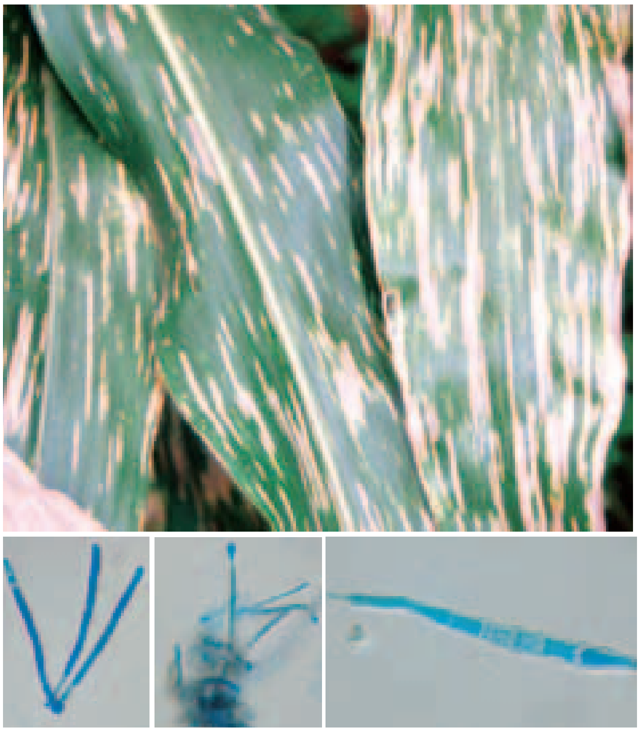

maize GLS – as well as the role of cultural practices in managing GLS, including reducing crop debris to reduce inoculum levels. The aim was to identify means of managing GLS effectively based on sound epidemiological principles, and to facilitate the selection of durable host resistance against the disease.

## ACHIEVEMENTS

The distribution and severity of GLS on small-scale maize farms in Kenya and Zimbabwe were quantified and mapped for the first time, confirming the threat to livelihoods from this recently introduced pathogen. Nationwide biological surveys of small-scale maize farms found that GLS occurred throughout Zimbabwe and, to a lesser extent, Kenya, with particular 'hot spots' around Harare and Kakamega. Over 500 isolates of GLS were collected during surveys and maintained in culture in duplicate collections. Taxonomic identification of >300 isolates revealed two different culture types which, based on morphology, conform to descriptions for *C. zeae-maydis* and *C. sorghi.* Studies using internal transcribed spacer sequences and amplified fragment-length polymorphism (AFLP) confirmed the existence and delineations of the two *Cercospora* species causing GLS: *C. zeae-maydis* (95%) and *C. sorghi* (5%). Isolates of *C. zeae-maydis* from Kenya and Zimbabwe were all found to belong to type II. The AFLP analysis showed the *C. zeae-maydis* population to be highly homogeneous, whereas the population of *C. sorghi* was highly heterogeneous. The low level of genetic diversity within populations of *C. zeae-maydis* meant there was little scope for further studies on the geographic distribution of the pathogen.

Cultural practices influencing the occurrence of maize GLS were identified through detailed socio-economic surveys of approximately

*Socio-economic survey of GLS in Zimbabwe*



*Above: symptoms of GLS on maize. Below from left to right: conidiophore and conidiogenesis; synnema; mature conidium of* Cercospora zeae-maydis *(photos courtesy of Dr Z.M. Kinyua)*

220 small-scale maize farmers in Kenya and Zimbabwe. Maize variety was found to play the key role in determining the occurrence of GLS – other factors included the removal of crop debris, and soil fertility (nitrogen). Poor awareness of the disease among small-scale maize farmers and extensionists, together with inadequate knowledge of the availability of resistant varieties in Zimbabwe (and a lack of resistant varieties in Kenya), are the major constraints to reducing the impact of maize GLS. Cultural practices found to influence the incidence and severity of maize GLS during the socio-economic survey were consistent with literature on the disease from other countries.

The epidemiology of the disease was established through field experimentation supported by the use of molecular markers. Extensive field trials established in Kenya and Zimbabwe quantified the effect of soil fertility, initial inoculum (infested crop debris), type of maize, maturity and fungicide use on the incidence and severity of the disease. Investigations into potential sources of inoculum failed to demonstrate the presence of *C. zeae-maydis* on over 15 potential alternative hosts, or on numerous imported aid shipments of grain (sampled using a DNA isolation kit). As inoculum from different sources has not been isolated, and genetic variability in *C. zeae-maydis* is extremely low, it was not possible to establish the disease epidemiology using molecular markers.

Investigations into the decay of *C. zeae-maydis* on maize debris over time were conducted using denaturing gradient gel electrophoresis and specific primers. The primers were extremely effective in detecting *C. zeae-maydis* in soil, and far exceeded results achieved using microscopy. The primers provided conclusive evidence that, if decay is speeded up by burying debris, the reservoir of *C. zeae-maydis* will decrease rapidly.

A standard protocol for screening for resistance in the field was developed and validated. This enabled the selection of suitable, locally available maize cultivars and provided support for maize breeding and selection programmes. Available germplasm in Kenya and Zimbabwe was screened using both natural inoculum in fields situated in disease hot spots, and artificially enhanced inoculum. The absence of pathogen variability, despite repeated sampling, precludes the need for host-resistance screening to take account of potential variability. A considerable amount of resistance exists in the germplasm in both Zimbabwe and Kenya, but whereas the majority of commercially available varieties in Zimbabwe have been bred for GLS resistance, that is not the case in Kenya.

An IPM strategy for maize GLS, including awareness-raising activities, was developed in consultation with Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), seed

*Farmers voting on the acceptability of the IPM Strategy*


*Small-scale maize farmers in western Kenya validating the IPM strategy for maize GLS*

companies, extensionists, farmers' groups and scientists. The basket of options includes cultural practices (removal/burial of infested maize debris), soil fertility and fungicide application (in Zimbabwe), as well as the use of resistant varieties. This basket of options was introduced to farmers within existing farmer field schools in western Kenya for the purposes of validation.

Two stakeholders' workshops on maize GLS were held, at CABI ARC in Kenya (2000) and in Zimbabwe (2003). Extensive training in the molecular characterisation of isolates of GLS was undertaken by two project scientists through attachments to CABI Bioscience, UK.

We now have a much clearer understanding of the variability (or lack of it) in the African pathogen population; the epidemiology of the disease; and management strategies appropriate for small-scale maize farmers. Of particular importance is the development of resistant maize varieties that are very early-maturing and therefore preferred by many small-scale farmers who rely on rainfed irrigation. Many of these new, resistant varieties no longer carry a price premium above traditional varieties.

## FURTHER APPLICATION

Outputs of this research have been promoted through farmer field days, open days, stakeholder workshops, videos and posters. Leaflets setting out options for the management of GLS have been published in English, Kiswahili and Shona and distributed to over 1500 farmers and extension officers. A poster, also in three languages, was disseminated to over 5000 farmers and extension officers. The advice offered can be directly taken up by farmers because the management of GLS is affordable and can be adopted with only small changes to existing farming practices. Despite this, there remains a lack of awareness among many farmers and extension officers about the existence of resistant varieties and other management strategies, and there is still reluctance among some small-scale farmers to switch from their 'traditional' maize varieties to the newer, resistant varieties. Take-up will depend on the promotion of resistant varieties and hybrids by seed companies, the extension service, NGOs, etc. Two projects in the CPP maize cluster could offer support in dissemination: project R8219 (page 76) has developed protocols for making small packets of crop seeds widely available to Kenyan farmers, and could probably assist in doing so for seeds of GLS-resistant maize cultivars; and project R8220 (page 73) is improving farmers' access to resistant maize cultivars in southern Tanzania. Information was shared between these and other maize projects at a CPP maize cluster meeting hosted by KARI in Embu during 2004. A short project to promote GLS management in Kenya, Uganda and Tanzania took place in 2005–06 (R8453).

The promotional materials developed have been disseminated to 8000 extensionists and farmers, and widely accepted. The posters are currently being used for training by agricultural extension staff and seed companies such as Seed Co Ltd, and there is increasing demand for more copies from other stakeholders, including universities.

# Improving farmers' access to and management of disease-resistant maize cultivars in Tanzania

**R8220**

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December 2002–March 2005

Tanzania has been without an organised system for local seed production and distribution since 2000, when the national seed company, TANSEED, collapsed. This situation had severely limited farmers' access to locally bred, certified and disease-resistant seed, particularly in rural areas. This project facilitated the establishment of a public–private partnership between ARI-Uyole and two private-sector seed companies in order to initiate a seed production and delivery system for the benefit of farmers in the Southern Highlands. The two seed companies embarked on certified seed production during the 2004/05 season, beginning with UH615, a hybrid validated by farmers. In order to ensure accessibility of seed to poor farming communities, both companies have agreed to start distributing seed in small packs (500 g to 1 kg bags), starting with the newly released hybrid UH6303. This step should enable sustainable access for farmers to improved certified seed maize, starting with the cultivars they have already validated through this promotional effort. These outcomes are likely to lead to increased maize productivity, contributing to poverty alleviation and sustainable livelihoods in the region.

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ARI-UYOLE (2004) Kanuni Za Kilimo Bora Cha Mahindi (Agronomic Recommendations for Maize Production). ARI-Uyole, Mbeya, Tanzania (leaflet in Kiswahili).

ARI-UYOLE (2004) Matumizi ya Mbolea Katika Kilimo Bora Cha Mahindi (Fertilizer Practices for Maize Production). ARI-Uyole, Mbeya, Tanzania (leaflet in Kiswahili).

ARI-UYOLE (2004) UgonJwa wa milia kwenye mahindi (Maize Streak Virus Disease Information Sheet). ARI-Uyole, Mbeya, Tanzania (leaflet in Kiswahili).

ARI-UYOLE (2004) Improving maize seed systems to meet farmers' needs in the Southern Highlands of Tanzania: Report of a Stakeholders Workshop on 29–31 July 2003, Iringa, Tanzania. ARI-Uyole, Mbeya, Tanzania.

GIBSON, R.W., LYIMO, N.G., TEMU, A.E.M. *et al.* (2005) Maize seed selection by East African smallholder farmers and resistance to maize streak virus. *Annals of Applied Biology* 147: 153–159.

TEMU, A., LAMBOLL, R., LYIMO, N., STATHERS, T. and GIBSON, R. (2005) Be Your Own Maize Doctor: A Guide Towards Nutrient Deficiency and Foliar Disease Symptoms in Maize Production. ARI-Uyole, Mbeya, Tanzania (leaflet).

## ISSUES

Maize is the most important food crop in Tanzania, accounting for 60% of dietary calories as well as up to 50% of utilisable protein for the majority of the Tanzanian rural population. It is the most widely cultivated crop in the country, covering about 45% of the area under annual crop cultivation. The Southern Highlands of Tanzania provide the most favourable climatic conditions for maize production, currently producing almost 50% of total national maize production. Up to 90% of the annual purchase of maize for the national strategic grain reserve is normally made in the Southern Highlands.

*Selecting maize seed in the field*

Poor access to quality seed by farmers has been a major constraint for a long time, not only after the collapse of the monopolistic national seed company, TANSEED, but previously during its over 20 years of existence in certified seed production and marketing. Most certified seed, which was marketed through a limited distribution network, had been of questionable purity and in many cases exhibited unacceptably low levels of germination. In addition, serious infections of grey leaf spot (GLS, caused by the fungus *Cercospora zeae maydis*; see R7566, page 69) and maize streak virus (MSV) have caused major losses.

In response to this situation, the Maize Improvement Programme (MIP) at ARI-Uyole embarked on a massive screening and evaluation programme of both local and exotic, commercial and pre-commercial maize varieties and inbred lines. The MIP developed several potential new maize hybrids, one of which (UH615) was officially released during the 2000/01 season. Given the urgency of the situation, seed production of this new variety was carried out swiftly through financial support from the World Bank. However, less than 50% of the 120 tonnes of UH615 hybrid seed produced by ARI-Uyole was taken up by farmers. Smallholders' scepticism about new technology may reflect the previous failure of TANSEED to provide good quality seed. Many farmers have lost confidence in the so-called new improved crop varieties from seed companies or from other institutions dealing with seed distribution.

In addition, stocks of a GLS-resistant version of the MSV-resistant TMV2 (open-pollinated variety) were available at Dabaga, a foundation seed farm. Other MSV-resistant (but not GLS-resistant) open-pollinated varieties are also available (e.g. Staha and TMV1). The Agricultural Sector Programme Support Seed Unit and the Tanzania Official Seed Certification Agency have made significant progress in developing a protocol for quality-declared seed (seed produced by a registered producer which conforms to minimum standards and is subject to quality control measures). This project builds on previous work and a number of community-based maize seed initiatives, for example in the Eastern and Northern Zones of Tanzania – including project R7429 in which Ugandan farmers learned about the principles of seed management and successfully multiplied seed of the MSV-resistant maize variety Longe 1 using a village-based system.

## ACHIEVEMENTS

Activities started with a baseline survey/situation analysis examining current access to and management of maize cultivars in target villages. Seminars to introduce the aim of the project to farmers followed, during which identification of training needs and formation of farmer groups were accomplished. Validation of new, disease-resistant maize cultivars was carried out by farmers and other stakeholders through village-based demonstrations in four target districts. In addressing quality seed production/supply-side issues and the current status of seed systems, a consultation survey of non-farmer stakeholders was carried out in the target districts, followed by a major workshop bringing together farmers and other stakeholders.

Increased awareness of disease-resistant maize cultivars (specifically for GLS and MSV) has been achieved through three seasons of on-farm demonstrations of new, high-yielding hybrids in four districts in the Southern Highlands of Tanzania. Some of these demonstrations were established in areas where no maize production technology had been presented to farmers for 20 years. These demonstrations have played a significant role in popularising the new materials, and have contributed to a recent increase in demand for seed in rural communities. There has been particular demand for UH615, one of the hybrids demonstrated. Another hybrid, UH6303, which was awaiting official release, was ranked first by most farmers in terms of preference in three out of four districts. This overwhelming farmer preference, in addition to other agronomic attributes, facilitated the successful official release of this material as a new maize hybrid for the Southern Highlands in December 2004.

Training needs have been identified with farmers and other stakeholders across the four target districts, during which farmers expressed demand for information/training at all stages of the crop cycle. With regard to seed management, demand related to modern and local varieties (for example, understanding differences between hybrids, open-pollinated varieties and landraces, and how to improve farmers' own seed). Needs for insect and disease management training included diagnosis and management information using both industrial pesticides and botanicals. Soil management featured significantly, and there was a high demand for information on both inorganic and organic methods of enhancing soil fertility.

Leaflets on agronomic recommendations for maize production, fertiliser use, general maize pathology plus one specifically on MSV, and on management of open-pollinated varieties, were developed as training tools. Farmer-group exchange visits were also used to address farmers' lack of knowledge of maize production and seed management. These training/learning tools, developed by a demand-driven approach, provide farmers and extension agents with current information and practices on maize production and seed management.

To address the issue of quality seed supply, it was necessary to consult widely to understand the perceptions, interests, activities and situation of stakeholders (including farmers, seed companies, stockists, NGOs, public-sector extensionists, researchers, regulatory bodies and policy-makers). This was achieved through various activities including a situation analysis with farmers; a consultation survey of non-farmer stakeholders; and a major workshop with farmers and other stakeholders. Three main systems (certified, quality-declared, and farmer-saved seed), which are more or less linked, were found to exist in the Southern Highlands and Tanzania as a whole. Strengths, weaknesses, opportunities and threats to each were explored with stakeholders, and opportunities were identified for improving each seed system.

Certified seed: a viable link with the

*Farmers inspecting a variety trials of high-yielding, disease-resistant hybrids*

private sector has been established following the efforts of the project to promote public–private partnerships in quality seed production and supply. Two private sector seed companies (Mbegu Technologies Inc. and Highland Seed Growers Ltd) have shown a keen interest in undertaking this endeavour, and have signed a Memorandum of Understanding with the Tanzanian Ministry of Agriculture and Food Security to participate jointly in research and development for mutual benefit between the two parties. The project has links with the Kenya-based Farm Input Promotions project (R8219, page 76) to share experiences in supplying mini-packs of agricultural inputs (seed and fertiliser) to resource-poor farmers.

Quality-declared seed: district and village extension staff from four districts were trained in the principles and practice of open-pollinated seed production. Farmers in Mbarali District received training (including a field visit to Njombe District) in quality-declared seed production.

Farmer-saved seed: a stakeholder workshop in Iringa helped raise the profile of farmer-saved seed in the Southern Highlands with a range of stakeholders, including policy-makers. Results from two demonstration seasons indicate that farmer-saved seed can perform well. For example, in one village in Mbarali District, farmer-saved Staha seed out-yielded certified Staha seed.

The project has encouraged the establishment of public–private partnerships between ARI-Uyole and two private-sector seed companies in order to embark on certified seed production and distribution. The commitment of these two seed companies to sustainable, quality seed production and distribution is demonstrated by their decision to absorb the costs involved in further screening of maize germplasm for disease tolerance at ARI-Uyole, to speed up the dissemination of more and better maize cultivars to farmers in the Southern Highlands and other parts of Tanzania.

## FURTHER APPLICATION

In the course of demonstrating and promoting new, disease-resistant maize cultivars, the project has identified other new resistant hybrids. There is a need to continue promoting these materials both within and beyond the project's target area.

The training tools, developed through a demand-driven approach, will play a significant role in addressing the lack of knowledge about improved maize production and seed management in the target area and the Southern Highlands in general, so that farmers may derive maximum benefit from the maize cultivars they have already validated. These tools need to be utilised more intensively and made accessible through a wider range of partners, both in the Southern Highlands, where zonal and district strategies have been developed with project partners, and eventually across Tanzania.

In an extension project (R8406) on improving Southern Highlands maize seed systems, improved links with the private sector, government extension and NGOs working with farmers will be employed to support the strategy.

# Improved access to appropriate integrated maize crop management by small-scale farmers in Kenya

**R8219**

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January 2003–March 2005

There are three major biophysical constraints to improved maize crop production by small-scale farmers in Embu and Kirinyaga districts in Kenya: poor soil fertility; prevalence of maize streak virus (MSV); and weeds. Use of appropriate farm inputs (fertilisers, disease-tolerant varieties and herbicides) is essential to increase yields. However, inputs are conventionally packaged in large-sized bags that are too expensive for most small-scale farmers. In addition, blanket recommendations for fertiliser that date back over a decade can result in the use of inappropriate nutrient applications to crops. The aim of this project was to introduce small-scale farmers to appropriate farm inputs and crop management. Methods used included dissemination through farmer field schools; small-plot demonstrations (maize varieties, fertilisers and herbicides); and promotions using small packs of products provided by the private sector. The companies involved cooperated by providing seed and fertiliser in small quantities to allow farmers to experiment with their use. This work has successfully addressed the role of the private sector in smallholder service provision, and has assisted this sector to become more responsive to the needs of smallholders.

## ISSUES

Production of maize by small-scale farmers in Embu and Kirinyaga districts of Kenya is well below crop potential. Maize varieties with a yield potential of 5–10 t/ha are available on the market, but yields in these districts are approximately one-tenth of what could be achieved. The increasing pressure on land due to a rapidly growing population means there is an urgent need to increase yields per hectare of cultivated maize.

There are three major biophysical constraints to crop production. First, soil fertility is very low, with widespread deficiencies of nitrogen and phosphorus. Low levels of fertiliser use also result in the depletion of other nutrients such as potassium and sulphur. Second, maize streak virus (MSV) disease is prevalent, resulting in up to 80% loss of yield in non-tolerant varieties. Third, crops suffer from competition from weeds due to ineffective and late weeding, often caused by a lack of available labour.

Use of appropriate farm inputs to increase yields is essential. Fertilisers containing the right blend of plant nutrients are required to alleviate the nutrient deficiency constraints; disease-tolerant, high-yielding maize varieties are needed to maximise crop response to nutrient inputs; and correct, focused herbicide applications are needed to control weeds while saving labour. However, inputs are conventionally packaged in large-sized bags, which are beyond the financial means of the vast majority of small-scale farmers, who survive on an income equivalent to about US$1 per day. For example, fertilisers are conventionally packaged in 50-kg bags that cost the equivalent of US$25.

*Maize yields were substantially improved by fertiliser application and the use of resistant varieties*

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*Private sector cooperators provided mini-packs of seed and fertiliser, which FIPS-Africa promoted to empower small-scale farmers to experiment with inputs on their own farms*

Previous research from western Kenya has shown that small-scale farmers are keen to purchase small quantities of appropriate fertilisers and improved seeds, in mini-packs costing as little as Ksh3 (3 pence). Farmers try these out on their own plots of land and, having 'learned by doing', return to their nearest stockist to purchase progressively larger packs as they see the returns on soil fertility, food security and marketable surplus. Use of this methodology has dramatically increased the demand for farm inputs among the poorest small-scale farmers in Kenya.

This project aimed to further develop and implement this methodology, in close cooperation with the private sector, to make the appropriate fertilisers, maize varieties and herbicides more accessible to small-scale farmers in Embu and Kirinyaga districts. An additional dimension was an investigation of herbicide use for crop protection within the framework of integrated crop management (ICM) for soil and water conservation. In this respect, the project aimed to build on a previous project (R7405, implemented by KARI), which identified labour constraints in land preparation and subsequent weeding as the limiting factor in maize production. That previous work found that controlling weeds by using herbicides resulted in significant reduction of labour requirement and also significantly increased maize yields.

## ACHIEVEMENTS

Demonstrations through farmer field schools (FFS) managed by KARI-Embu showed large yield increases due to fertiliser (44–179%), and through use of the MSV-tolerant variety WH403 compared with the conventionally used hybrid H513 (41–53%). Maize yields under conservation tillage were approximately 40% higher than under conventional tillage. In addition, the use of herbicides

*'Mavuno' fertiliser provided in affordable quantities leads to improved crop performance*

[glyphosate and atrazine+alachlor (Lasso)] in a no-till system reduced the cost of production by 50% compared with conventional tillage (digging and hand-weeding). Large increases in maize grain yields due to fertiliser use demonstrate the importance of the ICM approach used in this project. Failure to address the soil fertility constraint while concentrating solely on dissemination of crop protection strategies would result in reduced impact.

The project established a network of over 120 farm-input stockists throughout Central Province, who promoted the project outputs. Stockists were trained in the identification of MSV and the choice of varieties tolerant to the disease.

The project has attracted the support of the private sector to provide inputs in small quantities to allow farmers to experiment with their use. A fertiliser company, Athi River Mining, developed two new fertilisers (Mavuno and Mavuno Top) and packaged them in branded 1-kg bags. Western Seed Company, the supplier of MSV-tolerant varieties that performed excellently in demonstrations, supplied over 60,000 small 150-g packs of seed, free of charge, which FIPS-Africa distributed to farmers through stockists and farmer groups, and during field days. Monsanto agreed to package its Roundup Max product (glyphosate) in 100-g quantities.

A total of 500 farmers were trained by KARI-Embu staff in the use of herbicides, conservation tillage, fertiliser use and MSV-tolerant varieties through 12 FFS. In addition, FIPS-Africa conducted a total of 1500 small-plot demonstrations on small-scale farmers' fields in six districts over four seasons. 500 posters advertising 'Mavuno' fertilisers, commercially available MSV-tolerant maize varieties, and symptoms of nutrient deficiency and MSV were produced and distributed to cooperating stockists.

Thanks to the material and financial support from Athi River Mining

*Plants of an MSV-tolerant maize variety sampled from a demonstration showing response to different nutrient combinations (plant on the left is grown without nutrients)*

and Western Seed Company, the geographical range of the project was extended beyond the originally proposed target districts of Embu and Kirinyaga. Demonstrations and promotions were extended into Nyeri, Meru, Kiambu, Thika, Murang'a and Maragwa districts in Central Province.

The project succeeded in quickly raising demand among small-scale farmers for 60 tonnes of seed of new maize varieties, sold through stockists within the fourth season of the project. The majority of farmers purchased a 2-kg bag (the smallest size available). In addition, over 200 tonnes of 'Mavuno' fertiliser were sold in the project areas. Assuming the 60 tonnes of seed were used effectively with fertiliser to yield an extra 1.3 tonnes of maize grain per acre (0.53 t/ha), and it was used by 12,000 farmers each growing 0.5 acres of maize, then each farmer would harvest an additional yield equivalent to seven 90-kg bags.

## FURTHER APPLICATION

This work is helping to raise major issues about private-sector provision of inputs and improving farmers' access to knowledge. These issues include the lack of market research carried out by the private sector; the limited technical capacity of the private sector; an apparent inability to develop markets; and public-sector agencies that find it difficult to work with and enhance the private sector. There is potential to affect the future formulation and implementation of policy in this critical area.

An impact assessment has been carried out to determine the effect of the project on the adoption of inputs and on farmers' livelihoods. Data obtained will be used to fine-tune the promotion approach for future campaigns in neighbouring regions/countries. This methodology is continuing to be developed for the widespread dissemination of herbicide use, which is more complex than seed due to the greater need for effective training in terms of product knowledge and application methods.

Following the success of the project in Kenya, a pilot project was started in Tanzania to encourage the private sector to adopt the small-pack methodology and to empower small-scale farmers to experiment with small packs of seeds and new, improved fertilisers.

# Integrated pest and soil management to combat *Striga*, stem borers and declining soil fertility in maize

**R8212**

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October 2002–March 2005

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Maize grain yields in eastern Africa average less than 25% of potential yield. This low yield is caused mainly by witchweed (*Striga*) infestation, stem borers and declining soil fertility. 'Best-bet' strategies have been identified, developed and adapted for control of these three major constraints in Kenya, Tanzania and Uganda. This work has provided better understanding of the relative contributions of these constraints to the maize yield gap in the Lake Victoria Basin, and of farmers' indigenous coping strategies. The 'push–pull' crop rotation system; herbicide-resistant (imidazolinone-resistant) maize; and crop rotation have been tested in farmer-participatory trials. The project has helped build the capacity of farmers and national research and extension systems to conduct biological, ecological and socio-economic research on the integrated management of these constraints. A monitoring and evaluation system has been put in place to evaluate the new technologies and options, and to estimate their impact. The involvement of a large number of farmers should ensure a lasting impact at the local level, and hopefully a gradual diffusion of benefits to neighbouring areas.

## ISSUES

Maize is one of the most important cereal crops in eastern Africa, serving as both a staple food and a cash crop for millions of people in the Lake Victoria Basin. Grain yields under farmers' conditions average about 1–1.5 t/ha, less than 25% of the potential yield of 4–5 t/ha. The low maize yield is associated with several constraints. Farmers consistently list *Striga,* stem borers (*Chilo* spp., *Busseola fusca*, *Sesamia* spp.) and declining soil fertility as the three major constraints to efficient maize production in the region.

*Striga* is a parasitic weed that infests approximately 158,000 ha of arable land in the Lake Victoria Basin in Kenya alone. *Striga* can cause yield losses of 30–50%, although losses of up to 100% are not uncommon, with a value of the order of US$37–88 million per year.

*A farmers' field day in Siaya District, Kenya*

Stem borers seriously limit maize yields by infesting the crop throughout its growth stages. The yield losses incurred by maize vary widely in space and time, but range from 20–40% of potential output in eastern Africa, depending on agro-ecological conditions, crop cultivars, agronomic practices and intensity of infestation.

Soil infertility results from the poor inherent fertility status, together with high human population pressure, and poor soil and crop management practices. Due to the low inherent fertility status of the soils in the target region, their low buffering capacity, and the inability of small-scale farmers to invest in soil fertility management strategies, soils are rapidly degrading and are hardly able to sustain acceptable maize yields. Nitrogen and phosphorus are the major production-limiting nutrients.

A range of technologies addressing various aspects of *Striga*, stem borers and

*Project farmers use soybean rotations with maize to increase soil fertility and reduce* Striga *infestation*

soil fertility management have been developed and disseminated. These include the 'push–pull' technology for control of maize stem borers and *Striga* – maize is intercropped with the stem borer moth-repelling legume *Desmodium* ('push'), and stem borer moth-attracting ('pull') Napier grass is planted around the field (see page 84). Other technologies include herbicide-resistant (imidazolinone-resistant, IR) maize for the control of *Striga*, and various crop-rotation options for restoring depleted soils.

Research conducted at ICIPE showed that the root system of *Desmodium* in the push–pull technology, originally developed to control stem borers in maize, produces both *Striga* seed-germination stimulants and lateral growth-inhibiting chemicals, thereby hindering the attachment of *Striga*'s haustorial root system to that of the host plant (maize). The germinated *Striga* plant soon dies (suicidal germination). Research at CIMMYT has shown that, when applied as a seed dressing, the herbicide in IR maize (imazapyr) is imbibed by the germinating seed and absorbed into the growing maize seedling before any damage is inflicted on the host plant by *Striga*. Additionally, imazapyr from the seed coat that is not absorbed by the maize seedling diffuses into the surrounding soil and kills ungerminated *Striga* seeds.

This project developed and disseminated integrated pest and soil fertility management practices, in particular against stem borers, *Striga* and declining soil fertility, for maize-based production systems in the Lake Victoria Basin.

## ACHIEVEMENTS

Demonstrations of 'best-bet' technologies for the control of *Striga* and stem borers, and enhancement of soil fertility, were initiated in the long rainy season (March–July) 2003 in Kenya and Uganda, and during the more reliable second rainy season (October 2003–January 2004) in Tanzania. Components of these best bets were the maize–*Desmodium* (push–pull) intercropping system; continuous maize; and rotations with grain (soybean) and herbaceous (*Crotolaria*) legumes. Their effects on suppression of *Striga* and stem borers, and on soil fertility improvement, were compared using two maize varieties (IR and a local landrace or improved commercial variety) grown under two fertiliser levels (no or medium fertiliser). Stem borer damage to maize varied substantially between locations and seasons in all countries, and the push–pull technology was observed to suppress stem borer damage from the second (Kenya/Tanzania) or third (Uganda) season onwards. The IR maize fully controlled *Striga* emergence in Tanzania, and substantially suppressed *Striga* emergence in Kenya. In Uganda, IR maize did not show any effect on *Striga* emergence. The push–pull technology equally suppressed *Striga* emergence, but again only after two or three seasons. Other systems or fertiliser application did not result in significant reductions in either stem borer or *Striga* infestations. Differences in grain yields of maize between cropping systems were minimal, and only fertiliser application was observed to increase maize yield substantially in all countries.

Farmers from the target villages were exposed to the various options demonstrated during the first two seasons through field days in the villages. These formed the basis for the selection of options to be tested by farmers during the adaptation trials, which started during the long rainy season of 2004 in Kenya (148 farmers: 38% female farmers in Vihiga District; 60% in Siaya District) and Uganda (24 farmers in Busia District, 56% female), and during the second season of 2004 in Tanzania. Many of these farmers combine crop rotation with IR maize, or intercropping IR maize with push–pull technology. Preliminary farmer evaluation showed that in Vihiga District (Kenya), legume–IR maize rotations were preferred over the push–pull technology; while in Siaya District (Kenya), the push–pull treatments scored highly for all criteria. In Busia District (Uganda), soybean and *Crotalaria* rotations scored the highest.

A second set of farmer evaluations was carried out in six villages (Kenya and Uganda) in the short rainy seasons of 2003 and 2004, when 202 (in 2003) and 362 (in 2004) farmers participated. Results showed that in Siaya, farmers scored push–pull technology highly, while in Vihiga and Busia, *Crotalaria* and soybean rotations scored better. Treatments were significantly different, with women generally ranking the technologies higher than men in both Kenya and Uganda. The low-wealth-class farmers in Kenya ranked push–pull technology highly, while the high-wealth class ranked soybean and *Crotalaria* rotations better. In Uganda, low-wealth-class farmers ranked all treatments higher than their middle- and high-wealth-class counterparts.


*Push–pull intercropping for stem borer and* Striga *control*

The tech-nologies developed and dis-seminated are helping to reduce the vulnerability of small-scale farmers to the vagaries of different pests and the declining soil fertility that threaten their food security. The project is increasing local knowledge and capacity to deal with pest and soil fertility problems, leading to a sustainable increase in food production. Involving both private and public institutions such as seed companies, NGOs, agricultural extension and research bodies, will increase access to new technologies. To ensure long-term sustainability, the project is working exclusively through existing institutions.

## FURTHER APPLICATION

This work has demonstrated variability in the effects of these technologies, and has helped to clarify the possible limitations of the various inputs. For example, push–pull works better where there has been excessive rain and high *Striga* pressure; IR maize performs better where *Desmodium* cannot survive drought.

Follow-up activities (R8449) will yield conclusive information on the medium- to long-term effects of the best-bet options on the *Striga* seedbank, stem borer infestation, overall soil fertility status, and economic performance for the target areas. Farmers' assessment of the best-bet options requires several feedback cycles over several seasons due to the nature of the technologies evaluated (e.g. rotations require at least two seasons to assess residual effects), and the relatively high potential for drought around Lake Victoria.

The project will deliver its outcomes to a larger number of farmers within and beyond the target villages around the Lake Victoria Basin through enhanced links with farmer groups, NGOs, and other projects operating in the Lake Victoria Basin. The NGOs assisted include, in Kenya: CARE, Christian Relief Development Agency, the Kima Integrated Christian-based Rural Project, Sustainable Community Oriented Development Program, and Farming in Tsetse Control Areas; in Uganda: farmers' groups reached through links with NGOs such as Care for the Orphan, Widows and the Elderly, Busia District Farmers' Association, Farming in Tsetse Control areas, and Lumino Women's Development Association; in Tanzania, CARE-International, the Evangelical Lutheran Church of Tanzania, and World Vision of Tanzania.

Some components of the best-bet technologies require access to improved seeds and/or fertiliser. Public–private sector links with seed companies operating around Lake Victoria will foster access to seeds. The potential for alleviating poverty and spreading the products through areas beyond the target areas will be evaluated through impact assessment activities.

# Integrated pest management of maize-forage dairying in Kenya

**R7955**

**Joint-funded with Livestock Production Programme (LPP)**

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Dairying is an important source of household income on most smallholder farms in Kenya. As landholdings decrease in size due to subdivision, small-scale farmers cannot generate sufficient forage for dairying. A shortage of forage results in low milk production, long calving intervals, high calf mortality and low weight gain in young stock. Forage shortage is especially pronounced during the dry season. In central Kenya maize is increasingly being grown continuously for forage as well as for food on small-scale farms. Weeds from crop land are also an important source of forage for livestock. This CPP/LPP project aimed to assist maize–dairy smallholders to produce more forage for improved milk production through integrated management strategies that increase the seasonal availability of forage from both maize and weeds. The project investigated the effects of different maize cultivars, dense planting regimes and incidence of maize streak virus disease on grain yield, and on forage yield and quality. Also studied were the effects of different weeding regimes on grain and forage from maize and weeds; integrated management to optimise grain and forage production, including the push–pull system of reducing maize stem borer; and the farm-level economic implications of IPM strategies.

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## ISSUES

Maize is the staple food for 24 million households in eastern and southern Africa. Research into agronomic practices to optimise grain yields is a priority for the Government of Kenyan because of the critical role played by maize in food security. As a result, agronomic evaluation and crop husbandry recommendations for maize focus on maximising grain yield, but ignore the maize crop as a source of forage for livestock production, despite the value of the crop residue being between one-third and half the value of the grain produced.

In the Central Highlands of Kenya, dairying is the most important agricultural activity after tea and coffee growing. Dairy animals are fed in zero-grazed or semi-zero-grazed systems, mainly on 'cut-and-carry' forage maize residues, weeds, and crops such as Napier grass (*Pennisetum purpureum*). For example, in Kiambu District 48% of households stall-feed dairy cattle. Farming in this area is becoming more intensive as population size increases leading to pressure on the land, and producing sufficient forage for dairy cattle is expected to become increasingly difficult for farmers. Forage (in the form of maize thinnings and leaf strippings, weeds, and forage crops such as Napier grass) is abundant only during the rainy seasons. This project sought to increase forage production, and to promote small-scale silage-making technologies to conserve higher-quality forage produced during the rainy seasons for use during the dry season.

A survey of the Central Highlands found that localised, but often severe, epidemics of diseases and pests are present at levels likely to reduce maize yields. The most important are maize streak virus disease (MSVD); northern leaf blight (*Exserohilum turcicum*); rust (*Puccinia* spp.); anthracnose (*Colletotrichum* spp.); Fusarium foot rot; and stem borer (*Busseola fusca*). Weeds infesting maize crops (and non-cropped vegetation in adjacent land), while providing a measurable source of animal forage, also directly reduced yields in maize. Conversely, Napier grass and the legume *Desmodium uncinatum*, when grown in

*Farmers at a field day to promote sustainable maize–dairying*

association with maize, reduced the incidence of stem borer by repelling the adult insects then trapping the larvae. The negative and positive contributions of weeds and planted vegetation to livestock production must be integrated within the context of pest, disease and weed management.

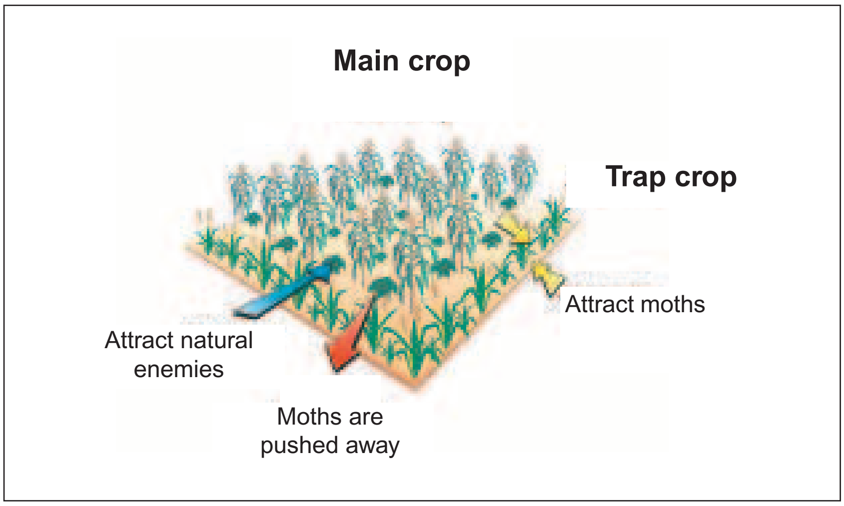
## ACHIEVEMENTS

The project first assessed all the impacts (biological, socio-economic, management) of MSVD and weeding regimes on the seasonal availability of forage and its quality in smallholder dairying. Farmers identified MSVD, maize stem borer and weeds as the three main biotic constraints in Kiambu. Most agronomic research on maize in Africa has ignored use of the crop as forage, and most farmers in Kenya were unaware of cultivars resistant to MSVD at the start of the project. The implications for IPM of feeding or composting diseased forage and weeds were explored, including studies of the 'push–pull' habitat management system for maize stem borer control which augments forage production by the maize crop with Napier grass and *Desmodium*.

The effects were quantified of maize genotypes, diseases and weeding regimes on total forage yield, forage quality and seasonal forage availability. MSVD was highlighted by farmers as having the greatest impact on maize forage and grain yields. It was also the problem about which they knew least in 2001. The project confirmed the deleterious impact of MSVD on yields of forage, and that these could be alleviated by growing resistant $F_1$ hybrid cultivars (PAN 67 and KH 521). These cultivars also performed well on- and off-station, and farmers confirmed their resistance to MSVD. The open-pollinated variety SADVEB also had some resistance to MSVD. This could benefit poor farmers who cannot afford $F_1$ hybrid seed.

Early infection was most damaging when all plants in a crop were infected artificially. A conflict in the scientific literature implied that early infection was not necessarily a problem when natural infections were investigated – this work demonstrated that where only 25% of plants were artificially infected 14 days after crop emergence, uninfected plants appeared to grow and compensate for infected ones. Partially infected crops could therefore give yields similar to infected ones, even though individual infected plants are stunted.

Farmer practices that aim to maximise forage production from the maize crop include high-density planting each season, with some plants being thinned to provide forage for dairy animals. Dense




*Layout of push-pull plot for maize stem borer control. Napier around the perimeter pulls (attracts) the moths while the Desmodium intercrop pushes (repels) them from the maize (illustration courtesy of Dr J. van den Berg/ICIPE, reproduced with permission of Taylor & Francis/CRC Press*)*

planting of maize was found to reduce weeds, but thinning for forage must be carried out carefully to avoid reducing grain yield. To obtain forage from weeds, some farmers leave them to grow for longer before the second weeding. In addition to the long-term effects of such practices on weed infestations, there are implications for disease and pest problems.

The IPM strategies promoted by the project comprised cultivars resistant to MSVD and maize head smut, and the push–pull system for stem borers. The recommendation is to plant three rows of Napier grass around the maize crop – Napier grass attracts (pulls) and traps the stem borer, preventing it from getting into the maize. A row of *Desmodium* planted between maize rows after every three to five rows of maize repels (pushes) the stem borer from the maize. Farmers in Kiambu and elsewhere have considerable problems with Napier head smut, and some therefore favour the resistant Napier cultivar Kakamega 1, which has never been tested in push–pull systems. Questions still to be addressed include whether the semiochemical production by Kakamega 1 will attract stem borer moths to a greater extent than maize; and whether semiochemical production by Napier and *Desmodium* will be adequate for attraction/repulsion of maize stem borer moths in different agro-ecosystems.

Both MSVD infection and weeds actually increased the quality of maize forage, especially in protein concentration. However, differences were small and were outweighed by the much higher total protein yield per unit land area from uninfected/weed-free maize.

The effectiveness was studied of routing maize and weed forage through ruminants, and of composting, in order to reduce transmission of maize diseases, stem borer and weed seed between seasons. The study focused on maize head smut, which can be soilborne. Spores could pass through the rumen, but were killed by composting. The only weed species that survived was *Amaranthus*: some of its seeds survived both rumination and composting.

The economic implications were quantified of maize diseases and farmer-acceptable weeding regimes for grain and forage yield, quality and seasonal availability for smallholder maize–dairy farmers and for landless women livestock farmers. The use of MSVD-resistant cultivars was shown to improve gross margins of MSVD-infected maize. The push–pull system shows negative returns in its first season, but thereafter is expected to be more profitable than current practice, even though stem borer infestations were insufficient to show a dramatic effect. The returns were substantial when combined with forage conservation to alleviate forage shortages in the dry season.

Extensionists and farmers were trained to promote sustainable maize–dairying, including how IPM may affect the availability of forage. Field days were held and specific training provided to extension staff and NGOs. Extension staff prepared action plans, and progress in these was monitored and evaluated. A website was developed (www.apd.rdg.ac.uk/Agriculture/Research/CropScience/Projects/IntegratedWeed/index.htm) and various items of literature supplied. Farmers were exposed to technologies by two field days and various exchange visits, and through a leaflet made available in English and Kikuyu.

## FURTHER APPLICATION

The project was extended until January 2006 to train promotion partners in IPM technologies and in participatory approaches. After training, follow-up support included supplying seed for trials, funds for farmer exchange visits and two review days. Only one year after training, promotion partners had, at their own expense, reached 31 farmer groups (351 men and 374 women); held 11 field days attended by over 4100 farmers while 190 and 498 farmers had adopted 'push–pull' and MSVD-resistant cultivars, respectively.

*KHAN, Z., HASSANALI, A. and PICKETT, J. (2006) Managing polycropping to enhance soil system productivity: a case study from Africa. pp. 575–586. In: *Biological Approaches to Sustainable Soil Systems*. Uphoff, N., Ball, A.S., Fernandes, E. *et al*. (Eds). Taylor & Francis/CRC Press, Boca Raton, FL, USA. ISBN: 1 574 445839 (in press).

# Improving food security and livelihoods through promotion of IPM in lowland maize systems

**R8215**

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October 2003–March 2005

Despite the importance of maize in the lowland tropical zone of Africa, yields in the region average less than 1.2 t/ha, compared with estimated potential yields of 4–5 t/ha. *Striga* infestations compounded by low soil fertility, diseases and pests are all constraints to improved yields. Although adverse climatic conditions were experienced during much of this project, the participatory research and extension approach (PREA) used led to improved soil and pest weed management techniques being adopted in target villages, indicating the success of PREA in allowing farmers and communities to identify and seek solutions for their own priority problems. There is evidence for considerable adoption of improved maize varieties (notably TMV1, Syn White and Syn 98) and, to a lesser extent, soil fertility and pest management practices. In the case of declining soil fertility, use of green manures has improved soil fertility and reduced *Striga* infestations. More widespread adoption will result from stakeholders promoting the technologies in other areas. This is likely to lead to a strengthening of the rural economy, with consequent advantages for local seed production and agents selling agri-inputs. The adoption of low-cost, labour-efficient weeding practices will release resources for other crops and non-farm activities. The combination of these outcomes in the long term should raise household incomes and improve basic food security, helping to alleviate the drudgery associated with hand labour, frequently carried out by women and children.

## ISSUES

Maize is important for household food security and as a cash crop for producers in the lowland tropical zone (0–1000 m above sea level) which stretches across Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Somalia, South Africa and Zambia. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) ranks maize as first priority among crops grown in the region, with low soil fertility, drought, foliar diseases (including streak), stalk borers, weeds and *Striga* among the priority constraints to improved maize production. CIMMYT, working in collaboration with the Eastern and Central Africa Maize and Wheat (ECAMAW) research network of ASARECA, has developed cultivars (open-pollinated varieties and hybrids) that are tolerant of moderate levels of *Striga* infestation, low soil nitrogen and drought, as well as being resistant

*A stand of improved maize Syn98 following the green manure* Canavalia

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AKULUMUKA, V., ELLIS-JONES, J., HELLA, J. *et al*. (2004) Improving food security through *Striga* and soil fertility management in lowland maize: a participatory development process. Paper presented at the International Weed Society Conference, Durban, South Africa, 19–24 June 2004.

ARI-ILONGA (2004) *Best Practices for Integrated* Striga *Control. A Group Extension Tool for Discussions with Farmer Groups. Users' Guide.* Agricultural Research Institute-Ilonga, Tanzania.

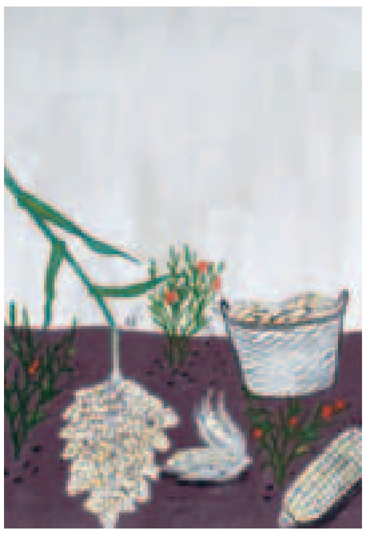
*Left, inspecting the green manure* Mucuna *in Mtakuja; right, illustration from* 'Best practices for integrated *Striga* control: a group extension tool'

to the major pests and diseases of the region. Additionally, CIMMYT has developed a novel technology for controlling *Striga* in maize, which involves the application of low doses of herbicide as a seed coating to herbicide-resistant maize varieties. These varieties are non-transgenic but derive their herbicide resistance from a naturally occurring mutation in maize that was identified and isolated by tissue culture.

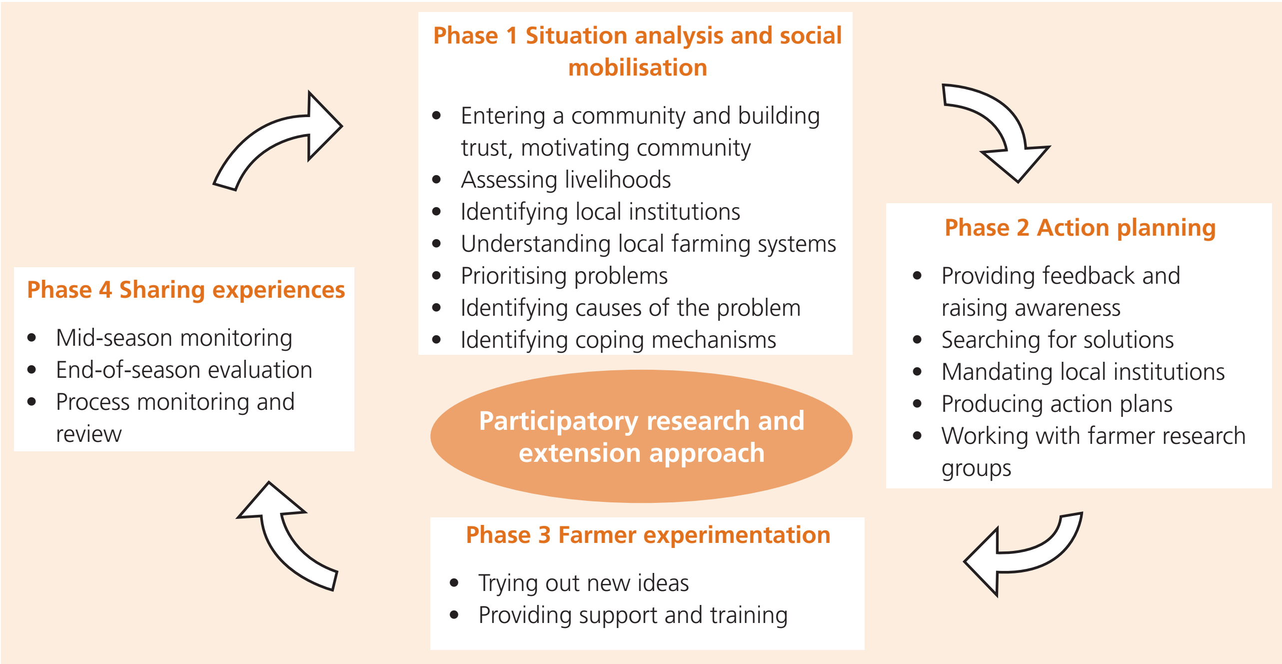
Trials undertaken by a previous project (R7564) have indicated that *Striga* alone can reduce yield by over 50%, depending on the cultivar, and that this effect can be reversed by the addition of nitrogen fertiliser or the use of leguminous green manures such as *Canavalia* spp., *Crotalaria juncea* or *Mucuna pruriens.* An added advantage of *Crotalaria* is that it produces *Striga* germination stimulant and has the potential to reduce *Striga* seed populations in the soil.

Maize streak virus, the main maize disease of the East African lowlands, is readily controlled by the use of host-plant resistance. Released varieties, including TMV1 and Staha, have been converted to carry resistance, but farmers are not always aware of sources of clean seed. One of the reasons for this is the widespread practice of recycling improved seed for many years before new stocks are purchased. Stem borers were reported by 54% of farmers in the Eastern Agricultural Zone of Tanzania to be the major pest of maize. Most farmers interviewed used no control method. Stem borer numbers can be reduced and maize yields increased by planting a trap-crop border of Napier grass (*Pennisetum purpureum*) around maize plots (see R8212, page 79; R7955, page 82). This practice needs to be tested with farmers in the Tanga region to examine farmers' acceptance of the practice and how it fits in with other production practices.

Work to support increased productivity of maize-based systems has been initiated through the Irish aid-funded EZCORE project (a programme within the Ministry of Agriculture and Food Security implemented by the district offices of the Department of Agricultural Extension). *Striga* infestation of cereal crops is a national research



*Illustrations from* 'Best practices for integrated *Striga* control: a group extension tool' *(dispersal by, left to right, wind and water; animals and tools; crop seeds*




*The participatory research and development approach used during the project*

priority in Tanzania, and work to identify *S. asiatica*-tolerant or -resistant maize lines is ongoing at Mwele seed farm in Muheza. This project was designed to respond to the need to test technology combinations in a participatory manner as a powerful strategy for technology development for both pest management and soil fertility enhancement.

## ACHIEVEMENTS

The project worked with key stakeholders using the participatory research and extension approach (PREA), ensuring that farmers and their institutions were fully involved from the outset. Evaluation of farmer-selected pest and soil fertility management options was carried out through farmer testing in Muheza District, Tanzania, selected as being representative of lowland maize production areas. This was based on participatory evaluation of appropriate maize varieties, alternative green manure crops, and low-cost methods of controlling stem borer over a two-year, four-season period. Although three of these seasons were adversely affected by drought, improvements were apparent with the improved rains in the last season of the project, ensuring that farmers achieved positive gains.

Ready access to inputs, particularly maize seed in small packs, was identified as important in promoting adoption. Two communities established their own seed-production units, and a private-sector company supplied improved seed in small packs.

Muheza District Council, in conjunction with EZCORE, has expanded activities to other parts of the district, and a considerable number of households are using at least one of the technology options. In particular, those farmers who have

*A village extension worker discussing green manure options with a farmer from Mbambakofi*

started to use new varieties of maize have achieved considerable increases in production.

Despite adverse climatic conditions during much of the project, improved soil and pest weed management techniques have been adopted in target villages, indicating the success of PREA in allowing farmers and communities to identify and seek solutions for their own priority problems. Close liaison between stakeholders (researchers, extension agents) and close involvement of policy-makers at village and district levels has ensured that wide scaling up should now be possible. EZCORE has used the findings to date, and expanded activities to a further six villages during 2004–05.

## FURTHER APPLICATION

Benefits from increased productivity have so far been assessed only over a very short period, necessitating a further year of activities (R8452) that will build on existing farmer trials and their use within a farmer group training approach, and training of trainers in conjunction with EZCORE/District Agricultural Office. The sale of seeds in small packs will be promoted through the establishment of village-level supplies linked to local seed production.

# Promoting improved crop establishment and weed management in semi-arid sub-Saharan Africa

**R8191**

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*CARE, Zimbabwe*

*Africa 2000, Zimbabwe*

*Zimbabwe Farmers Union (ZFU)*

*Agricura, Zimbabwe*

*Cotton Company of Zimbabwe (Cottco)*

*Monsanto*

*SeedCo*

*Windmill*

*Zimbabwe Fertilizer Company*

September 2002–March 2005

See R6655, *Perspectives on Pests 1996–2000*, p. 4.

Over 80% of smallholder, subsistence farming households in Zimbabwe live below the basic needs poverty line. The number of small-scale farmers in rural areas is growing, but at the same time their contact with markets and transport facilities are declining. Building on research outputs from a number of CPP projects, knowledge and technologies for improving crop productivity in cotton and maize systems were identified and developed with both extension workers and farmers. AREX, farmers, the private sector, NGOs and commercial companies were all involved in developing a process for testing a range of crop establishment and weed management technologies targeted at resource-poor farmers in the small-scale sector. A process approach was developed for farmer testing of these practices. The capability of participating organisations has been strengthened through the use of participatory approaches, training in the technologies, and improvements to research–extension–farmer–private sector links. However, the potential impact will remain limited until political and economic circumstances in Zimbabwe allow the redevelopment of an effective extension service with an efficient input-supply network.

## ISSUES

In Zimbabwe, crop and livestock production are increasingly central to people's livelihood strategies. However, following the drought in early 2002 people are being forced to diversify into unsustainable, riskier and sometimes illegal coping strategies such as gold panning, poaching, sale of fuelwood and thatching grass, piecework and illegal cross-border trade. At the same time, new vulnerable groups are emerging, including the elderly and children caring for HIV-affected people. Traditional safety nets are breaking down under pressure, notably those of the extended family under pressure of the burden of AIDS and the rising cost of living.

Unfortunately rural people are increasingly distanced from input and output markets, and communities are interacting less with the outside world due to rising transport costs. Rather than the usual picture of urban-to-rural migration, the reverse is now true – people are moving back to rural areas due to urban unemployment. Devastating droughts in both 1992 and 2002, especially in the southern parts of Zimbabwe, have led to increasing concerns about food security and overexploitation of natural resources.

This project aimed to assist the 80% of small-scale farmers who live below the poverty line. Within this group, four categories have been identified, ranging from relatively well resourced to very poorly resourced, distinguished by access to physical assets (draught animals, implements), natural assets (land), and financial assets (especially non-farm income, which is rapidly declining). Households headed by women, especially where the head is widowed, separated or abandoned, are among the poorest. Different levels of access to resources make it particularly important that a range of technology options is available, from no-cost (such as seed priming) to high-cost (such as herbicides).

Low-cost, labour-efficient options for soil and weed management in seasonally inundated land (*vleis*) in maize–rice and cotton–maize production systems in the Zambezi Valley have been the subject of a number of previous CPP projects over the period 1996–2002 (R5742, R6655, R7189, R7440, R7473, R7474). That research developed appropriate and applicable technologies to improve

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CHIVINGE,O.A. (2004) Fight against weeds. *Harvester* 1(5).

UoZ, SRI, NRI, AREX, COTTCO (2003) Guidelines for Farmers. 13 leaflets on: land preparation, ploughing options, minimum tillage, soil conservation, third burrow planting and ripper planting, hand and opening plough furrow planting, weeding options, ploughing with dish remover, ploughing with dish attached, weeding with a cultivator, weeding with a cultivator with hillers, using herbicides, and safe use of pesticides. Farmer leaflet nos UZ/03/01-UZ/03/12V.

*Assessing increases in rice and maize yields*

crop production, increase income generation, reduce poverty, improve health and nutrition, improve food security, reduce labour demand (especially for women and children), and increase livelihood options. The current project aimed to promote these research outputs through communicating the knowledge and technologies to extension workers, farmers and other relevant stakeholders.

## ACHIEVEMENTS

For each component of the project, seven training modules were developed with 12 leaflets in English and Shona for each. A total of 40 farmer study groups (800 farmers) were formed. With farmers and field staff in government, NGOs and the private sector, the project developed and tested a participatory research and extension approach involving a four-phase cycle: situation analysis and social mobilisation; action planning; farmer experimentation; and sharing experiences.

The participatory approach was used to identify adoptable technologies and promote scaling up in two areas of Zimbabwe:

- parts of Masvingo Province, south-east Zimbabwe, where farmers prioritised improved utilisation of *vlei* (swamp) areas
- the Zambezi Valley in northern Zimbabwe, where priority was given to maize–cotton systems.

The establishment by lead farmers of test and demonstrations plots was facilitated by AREX, Cottco, CARE, Africare and ZFU over three years. These test plots involved various technologies chosen by the different farmer groups, depending on their available resources and environment, as follows.

*Vlei* utilisation (Masvingo):

- alternative maize–rice planting systems
- seed priming
- soil and water management, including flat, bed and ridge systems
- improved use of ploughs and cultivators in crop establishment and weed management
- use of herbicides.

Cotton production (Zambezi Valley):

- soil and water management options, including reduced tillage
- improved use of ploughs and cultivators in crop establishment and weed management
- use of herbicides in combination with hand and draught-animal weeding equipment.

In all cases, lead farmers from each group provided facilities for testing the new technologies, with others in the same group encouraged to learn from and try the technologies on their own farms. In Mshagashe, for instance, there has been a steady increase in the number of farmers adopting the technologies.

Some major external factors had a severe impact on stakeholders' abilities to support project activities from their own budgets. Extremely dry conditions in the first and third seasons of the project resulted in partner organisations, particularly NGOs, changing their priorities to food relief. Deteriorating economic conditions in the country led to a serious rise in input costs (over 1000% in two years). Initially the project had worked with the private sector to improve farmers' access to inputs, but economic conditions resulted in huge increases in costs, unavailability of many items and the withdrawal of many suppliers from rural areas. As a result, the project took over the role of input provision in many cases. In addition, changing government priorities such as the fast-track land resettlement resulted in AREX extension staff being assigned new duties.

Despite these restrictions, the project has demonstrated an enhanced dissemination process providing farmers with improved access to information about production-increasing technologies. Given normal weather conditions, these technologies have the potential to increase income generation, improve livelihoods and reduce poverty. Training kits, incorporating a trainer's manual, posters and farmer leaflets, have been developed for use by the extension services, and electronic versions are being provided to institutional stakeholders for further dissemination.

## FURTHER APPLICATION

Further scaling-up activities are needed to raise awareness of senior staff in stakeholder institutions of the potential gains of using this approach to scaling-up technology adoption. Training of trainers in the use of the training kits developed by the project is needed at both provincial and district levels, as well as subsequent training of extension workers so that farmer training can be incorporated into local-level programmes.

# Promotion of IPM for smallholder cotton in Uganda

**R8197**

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September 2002–March 2005

See R6734, R6760, *Perspectives on Pests 1996–2000*, p. 95

Average cotton yields in Uganda are well below the potential for rain-grown cotton, mainly due to problems with crop management and pest control. Despite poor world prices for cotton, it can still be a profitable crop for African smallholders with appropriate crop management and crop protection. This project aimed to develop an IPM system appropriate for smallholder cotton in Uganda to complement an agronomic package being promoted by a USAID-funded project (IDEA, later APEP). The IPM system was based on delayed first use of insecticide by using soapy water to control early-season aphids, followed by scouting-based application of broad-spectrum insecticide sprays for control of bollworms and lygus bug. A simple wooden peg-board was designed as a scouting aid for farmers. The combined agronomic and IPM system was promoted through 6000 on-farm demonstrations, which depended for their success on close collaboration with private-sector ginning companies. The eight main ginning companies operating in Uganda provided a total of 600 extension personnel who were trained in IPM and became 'site coordinators'. The involvement of the private sector ensures that IPM knowledge will continue to be transferred to cotton farmers long after the end of the current projects.

## ISSUES

Between 1945 and the early 1970s, Uganda became the leading producer of upland cotton in sub-Saharan Africa. Regional and internal conflict in Uganda in the 1970s and 1980s saw production decline by more than 90%. Rehabilitation of the cotton industry in the 1990s was supported by the International Fund for Agricultural Development, and public and private investment in the cotton industry has seen production levels recover to around one-third of 1970 levels. The IDEA Project (later APEP), funded by USAID, began in 1998 to promote improved cotton agronomic practices through a programme of on-farm demonstrations. Later, USAID approved an expansion of the cotton on-farm trial programme under APEP, with a target of 12,000 on-farm trials by 2007.

*Several thousand wooden peg-boards were manufactured to aid scouting*

Falling world cotton prices in the latter half of the 1990s, and continued problems with marketing, are discouraging farmers from growing the crop where there are alternative sources of cash income. But in the drier areas of north-eastern Uganda there are few reliable alternative cash crops, and at least 400,000 households depend on cotton for cash income. With the falling world price for coffee and the cotton price beginning to pick up,

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RUSSELL, D.A. (2003) *Integrated Control of Pests, Weeds and Diseases in Ugandan Cotton. A guide for use with the SPEED IDEA cotton demonstrations.* SPEED and IDEA Projects, Kampala, Uganda.

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*Photographs taken for training manuals were used by the agrochemicals company Balton to produce a laminated insect identification sheet, used by farmers in the field to identify pests and beneficial insect species*

increased cotton production will play an increasingly important role in the national economy.

Collaboration with the IDEA Project through its network of on-farm demonstrations allowed this project immediate access to promotion sites and participating farmer groups.

## ACHIEVEMENTS

Lessons learned from a successful CPP project in India (R6734, R6760), which demonstrated that IPM can be enthusiastically adopted by cotton smallholders to decrease their dependency on insecticides, were used to develop an IPM model for Africa. The main cotton insect pest in Africa is the same as in India, the bollworm *Helicoverpa armigera*. In Uganda, in collaboration with SAARI, NRI scientists developed an IPM model for use by cotton smallholders.

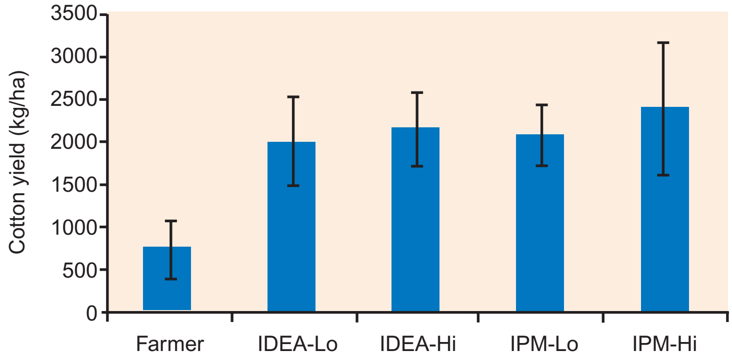
IDEA was initially recommending a calendar-based spray regime of four sprays at three-week intervals from first flowering. Smallholders were receiving enough insecticide for only two sprays with their seed in a 'starter pack', and often used their first spray before first flower to control aphids.

An appropriate IPM system was designed and evaluated in Kasese. First insecticide use against aphids was eliminated by using soapy water. As a scouting aid, a simple wooden peg-board was used to record key pests, with insecticide applied only when a set threshold number of pests was reached as marked on the board. By this system, the number of insecticide sprays was reduced from four to two or three, without loss of insect control. The system received approval from IDEA and from USAID. In the following season in Pallisa (Teso), the IPM system was adopted on 300 on-farm trials and on a further 300 in Kasese in August 2003. When the cotton demonstration programme developed by IDEA was expanded under a new USAID project (APEP) in 2003, IPM adoption was scaled up to reach 6000 on-farm trials by the end of 2005.

In order to achieve these levels of adoption of the IPM system, a large training-of-trainers programme was initiated. The private-sector ginning companies were enthusiastic, and their participation increased from two companies in 2002 to all ginning companies in Uganda by 2004. The ginning companies provided site supervisors for the on-farm trials, who were trained in IPM. This involved training workshops, the production of training guides and an IPM video. More than 600 site supervisors were required for the on-farm trials by the end of 2004. Each supervisor trained 10 demonstration farmers in IPM (or, if the IDEA agronomic package is included, in integrated crop management, ICM). Each of those farmers was expected to pass the knowledge on to at least 15 neighbours, friends and relatives. On this basis it was estimated that 180,000 cotton farmers would be exposed to the ICM technology by the time the target of 12,000 cotton on-farm trials was reached in 2005/06.

Together with the National Cotton Programme at SAARI, 25 on-farm trials were set up within the Teso farming system area. These trials showed that while, overall, there was an economic

*Drying cotton in Uganda*




*Seed cotton yield from IPM plots compared with other IDEA plots and farmers' unsprayed plots in Kasese, 2002/03 season*

benefit from fertiliser use, on an individual basis only three farmers obtained a yield increase that was statistically significant. Replacing one ploughing with reduced tillage based on herbicide use was also found to be cost-effective. Intercropping with beans, a common practice among cotton farmers, was shown to be a risky strategy, decreasing cotton yields and giving poor or even zero bean yields on sandy soils.

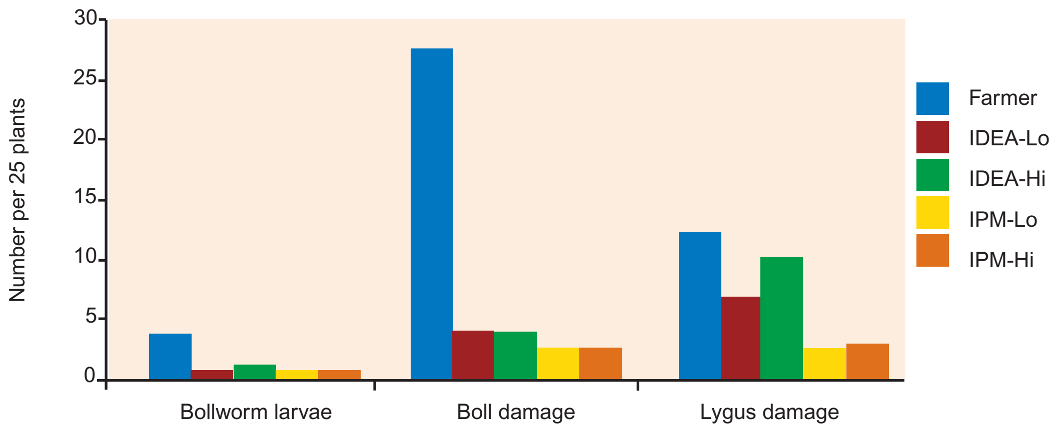
Socio-economic studies showed that medium- rather than small-scale growers are the poorest cotton growers, as measured by ownership of physical assets. Poorer growers hire less labour for land preparation and weeding, suggesting that they lack sufficient working capital for cotton cultivation. The frequency of cotton spraying is determined by asset ownership and cash availability, rather than knowledge of cotton cultivation. Among poorer medium-scale growers, the route to higher productivity lies through planting less cotton but managing it more effectively, particularly by weeding and pest control. Yield increases might then compensate for the reduction in the area planted. Some level of insecticide use is almost universal, and all growers would benefit from IPM that reduces the number of sprays required. By reducing the cash needed for pest management, IPM would save poorer growers money and improve the timeliness of spraying. However, as poorer growers plant more cotton than they can manage because they lack alternative sources of cash income, improving productivity among this group might depend on opportunities for diversification into other cash crops or into off-farm employment.

The project has shown that farmers are keen to adopt knowledge-intensive technologies provided appropriate training is given, and that the private sector is willing and able to invest in service delivery where there is clear commercial benefit.

## FURTHER APPLICATION

A short follow-up project (R8403) will complete the scaling up to introduce IPM to all the cotton demonstrations in the country, and will assess the success of the programme in terms of technology adoption outside the demonstration farms.

The private agricultural sector is weak in sub-Saharan Africa, and companies do not have a clear vision of how they can act to increase production and improve smallholders' access to markets. Private companies and farming communities need to be persuaded that there will be economic benefits to their collaboration, and this can be facilitated by close collaborations with donor-funded projects of this type.




*Pest incidence in IPM plots compared with other IDEA plots and farmers' unsprayed plots in Kasese, 2002/03 season*

# Novel technologies for control of African armyworm on smallholder cereals in East Africa

**R7954**

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January 2001–July 2004

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MUSHOBOZI, W.L., GRZYWACZ, D., MUSEBE, R., KIMANI, M. and WILSON, K. (2005) New approaches to improve the livelihoods of poor farmers and pastoralist in Tanzania through monitoring and control of African armyworm, *Spodoptera exempta. Aspects of Applied Biology: Pathways out of Poverty* 75: 37–46.

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African armyworm (*Spodoptera exempta*) is a serious migratory pest of pasture and grain crops in Africa. Outbreaks occur every year in primary outbreak areas of Tanzania, and under favourable conditions the armyworm can then move across Tanzania and migrate to many parts of eastern and southern Africa. This project aimed to develop and evaluate two novel approaches to replace environmentally damaging and expensive synthetic chemical pesticides to control African armyworm: applying *S. exempta* nucleopolyhedrovirus (*Spex*NPV), a naturally occurring biological control agent; and neem, a locally available botanical agent. Field work confirmed that the candidate technologies work well in practice, and both were used successfully in small-plot trials and for large-scale aerial application (the first use of aerial application for any NPV biopesticide in Africa). In Tanzania the use of *Spex*NPV has been adopted as National Policy, and local neem is being promoted in target districts by the PCS. Work has started on adapting an existing Brazilian production model for NPV which should lead to a stable product that is affordable for poorer farmers in Tanzania. Benefits of this research will accrue throughout Tanzania, with likely spillover benefits for surrounding countries.

## ISSUES

Poor farmers are especially vulnerable to armyworm outbreaks. Losses due to armyworm may be virtually zero in some years, and immense in others. Yield losses within an outbreak area may be very high, although 30% loss in recently planted maize has been estimated as an average loss. Armyworm populations often originate in game parks and environmentally sensitive areas; there are also growing environmental problems with the stockpiling of pesticides. Reducing the impact of armyworm attack in Tanzania currently hinges around the timely supply and use of effective pesticides, supported by a centralised forecasting unit (the PCS). Concerned about the environmental effects of wide-scale pesticide use, and the high cost of imported pesticides, the Ministry of Agriculture and Food Security in Tanzania sought assistance to develop better armyworm management based on biological control. Under a previous project (R6746), the *Spodoptera exempta* nucleopolyhedrovirus (*Spex*NPV) was evaluated in the field in Tanzania. Following on from that work, this project aimed to continue field testing and work towards sustainable production of the virus; and also to examine the use of the local botanical agent neem as a possible tool for armyworm management.

*Project findings on* SpexNPV *have been disseminated widely in the local and international press (from Dalyell, 2004, courtesy of* New Scientist*)*

## ACHIEVEMENTS

An initial workshop was held to discuss the project with stakeholders and plan project activities in detail. This generated a better understanding of those who are at risk from armyworm outbreaks, and of the appropriateness and adoptability of the proposed technologies.

The laboratory work had shown that both *Spex*NPV and neem could kill armyworm, and initial field trials confirmed *Spex*NPV could be effective at application rates [$5 \times 10^{11}$ to $5 \times 10^{12}$ occlusion bodies (OB) per hectare] that would be practical in the field. A survey of farmers confirmed that neem was available in armyworm outbreak areas, and could therefore be harvested and used where resources were not available to purchase pesticides.

Working with a sporadic, migratory pest such as armyworm makes it difficult to obtain trial data in some years (such as 2001 and 2003), but field trials in 2002 did demonstrate that *Spex*NPV can be used successfully to control armyworm outbreaks. Progress made by the project attracted additional funds from USAID, which enabled aerial spraying trials of NPV to be carried out. In both the major field trials in 2004 (aerial and ground), application of *Spex*NPV was followed by armyworm population collapses and the appearance of large numbers of *Spex*NPV-infected and killed larvae.

Overall, the trials showed that *Spex*NPV can be as effective as chemical insecticides in controlling armyworm, when applied at rates as low as $1 \times 10^{12}$ OB per hectare using ground-based or aerial application. PCS is committed to controlled expansion of the scope of field trials, including yield trials, to ensure that this technology is sufficiently robust before full replacement of chemical control by *Spex*NPV is adopted.

The same trials also showed that simple extracts of neem leaves and seeds can be used to kill armyworm. While these are not as effective as either chemical insecticides or NPV, use of neem should be useful to local communities who lack access to other resources. Local neem may be highly variable, but the results to date indicate that neem can be of value where no other control options are available. It is the intention of PCS to conduct participatory field trials during the next few years to validate neem and determine its utility and reliability.

*Major armyworm outbreaks can decimate cereal crops*

Ecological studies have shown that *Spex*NPV is widespread in Tanzania in adult armyworm moths, but is found as a non-symptomatic, or latent, infection – the first scientific confirmation of a latent NPV in an African insect. The role of these non-symptomatic infections in relation to natural outbreaks of overt lethal NPV disease in larvae is not yet clear. However, the *Spex*NPV disease is likely to be an important factor influencing the population dynamics of armyworm, and understanding this relationship could be a major breakthrough and a key to better forecasting of outbreaks. A reliable method of forecasting outbreaks will greatly enhance the application of control methods, and progress towards this has been made by the linked project R7966 (see page 96).

The virus is present as a wide variety of genotypes, 60 of which have already been identified and collected. A number of these genotypes have been cloned and assayed, but none has proved individually to be more pathogenic than the wild type used in the field trials.

For scaling up production of the virus, field trials confirmed that it is a viable strategy in Tanzania to produce *Spex*NPV for armyworm control by spraying naturally occurring armyworm outbreaks with an inoculating dose of *Spex*NPV, then harvesting the diseased larvae.

*Farmers discussing armyworm forcasting and control with the research team under neem trees in central Tanzania*

*Field trials included the first use of aerial application for any NPV biopesticide in Africa (with funding from USAID)*

The head of PCS in Tanzania visited EMBRAPA in Brazil to be trained in low-cost NPV production techniques. He judged these to be appropriate for use in Tanzania, and that the techniques could produce armyworm NPV at a cost comparable to that in Brazil (US$3.00 per hectare). This is much lower than the current cost of imported synthetic insecticides (around US$10 per hectare). Initial work has shown that the clay-based formulation developed by EMBRAPA can be produced for use in Tanzania. The system for harvesting infected field populations needs additional work, as the Brazilian larval collection system is not appropriate for African armyworm. The development of low-cost NPV is crucial – the cost of chemical insecticides is the major reason why 65% of poor farmers cannot control armyworm.

Neem leaves can be used in the many areas where neem is already planted as a shade tree. Some 50–80% of farmers have neem trees, and their leaves and/or berries could be used to protect cereal crops by the majority of smallholder farmers. The high bulk of neem needed and high transport costs mean it is not feasible to recommend its use for strategic control on a large scale, where NPV is more practical.

A strategy to disseminate the project's findings to a wide range of clients has been implemented, including articles in local and international newspapers and popular journals; TV broadcasts in Tanzania; and leaflets and posters.

Institutional capacity in PCS Tanzania has been improved by staff receiving training in the production and use of both NPV and neem.

## FURTHER APPLICATION

Tanzania has agreed as National Policy, through its National Plant Protection Advisory Committee, to adopt *Spex*NPV as the replacement for chemical pesticides for armyworm control. PCS will continue to promote the use of *Spex*NPV through its own channels, and the findings of the project will inform the USAID-funded armyworm control project. The use of neem is currently being promoted to farmers in several trial districts by PCS, as part of the armyworm control project funded by USAID and the Government of Tanzania.

However, while the field use of *Spex*NPV is proven, research is still needed to develop a system for mass harvesting the NPV cheaply and in bulk, and is being undertaken in the 2005 field season (R8408).

The results are being disseminated to interested African countries (Kenya, Uganda, Mozambique, South Africa, etc.) and organisations mandated to lead regional armyworm control, such as the Desert Locust Control Organization. Some countries, such as Kenya, already have the legislation in place for adoption of biopesticides as a result of other CPP activities.

# Improved armyworm monitoring and forecasting systems

**R7966**

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October 2000–March 2004

Cereal yields in East Africa are highly variable due to the unpredictability of the climate and of pest attack. This variability is a key constraint to rural development, causing periodic crises and hardship for rural communities. Improved forecasting of sporadic but serious crop pests is vital to reduce this variability, making it possible to improve the supply, targeting and timing of pesticides or biopesticides. This project focused on African armyworm in Tanzania. The work has demonstrated the feasibility of village communities making armyworm forecasts, potentially decreasing the response time for control interventions. Community-based forecasting represents a significant paradigm shift in migrant pest forecasting away from the prevailing view that, as migrant pests are international, their forecasting should be tackled by centralised organisations. This project demonstrates that forecasting at a village level is both feasible and can be complementary to the national service.

## ISSUES

Armyworm (*Spodoptera exempta*) causes devastating but highly localised damage to cereal crops and grasslands. It is mainly a problem in eastern Africa, but also occurs in southern Africa. Losses due to armyworm are virtually zero in some years, and immense in others. Insecticides or biopesticides can control the pest, but only if they are applied within a narrow time window – after the eggs hatch, but before the larvae become large enough to cause significant damage. The protection of crops from armyworm requires that intensive scouting is carried out in areas of high outbreak risk; and that insecticides and government application teams or farmers are in the right place at the right time to treat the localised, but often large, infested areas. Forecasting has a key role in both tactical and strategic control: short-term forecasting to guide scouting operations, and medium-term forecasting to manage the control logistics. Tanzania is particularly important for strategic control because the first armyworm outbreaks of the season frequently occur there before spreading out to other parts of eastern Africa.

The Pest Control Service (PCS) of the Tanzanian Ministry of Agriculture and Food Security already runs a forecasting service. The new forecasting tools being developed are intended to extend their capabilities and increase the efficiency of their operation, and were developed jointly with the forecasting services through a process of evaluation and feedback in a series of mini-workshops. The current project also built on a wealth of information from previous research funded by DFID and others, including an earlier project (R6762) which developed a system for the weekly processing and provision of Meteosat data. A related project (R7954, page 93) is researching novel technologies (biopesticides) for armyworm control in East Africa.

## ACHIEVEMENTS

A planning workshop in Arusha, Tanzania, involved a wide range of stakeholders in examining the current state of armyworm management and planning further development of existing armyworm forecasting methods. A series of 'evolution workshops' held throughout the project's lifetime allowed continual re-evaluation of its direction and activities. In response to this feedback, two substantial changes in the project from its initial conception concerned the

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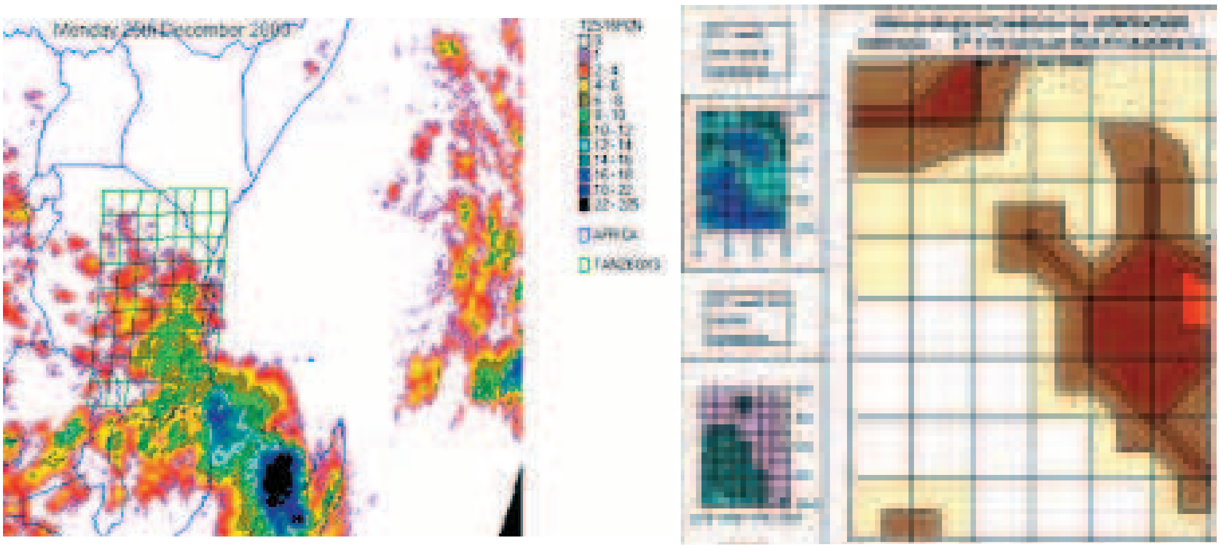

*Data are recorded from the Meteosat satellite on the number of hours of rain in a day (daily cold cloud duration). These data are stored in the form of a false-colour image of the area acquired (left). Maximum values are extracted for each degree square in central and east Tanzania. Daily data are contoured (top right), combined with data from the previous week, to give a two-week rainfall sequence. The contour chart of meteorological risk is forwarded to Arusha. Examination of the historical armyworm database for Tanzania shows that this is a good estimator of the risk of armyworm outbreaks during October–May. Armyworm trap-catch data can then be considered in conjunction with the meteorological conditions in order to reach a prognosis for the armyworm outbreak risk.*

expansion of activities geared to the development of community forecasting; and the development of new computer software to handle the data management needs of the central forecasting operation.

Real-time, spatially accurate rainstorm data are used in the centralised armyworm forecasting. Based on Meteosat images, the likelihood of storms on each day and in each district of Tanzania is made available to the national forecaster for a weekly armyworm outbreak forecast to be formulated and issued.

An armyworm website was established to provide the Meteosat rainstorm information and corresponding outbreak forecasts. This information, together with pheromone-trap and rain-gauge data, can now be stored and collated in such a way that the necessary information can be compared by the national forecaster in order to make the weekly forecast for each district. The software to do this (WADI), developed by the project in ACCESS 2000, provides a 'Windows Armyworm Database Interface'.

For community-based forecasting, simple rules have been developed to allow farmers to make forecasts based on a single rain gauge and pheromone trap. Testing in five pilot study villages indicated that these rules were providing good forecasting accuracy even before trap calibration – which will be possible only when data exist for the traps concerned. During the first year of the pilot study, traps were run successfully and forecasts made in all the participating villages.

Analysis of historical armyworm data allows comparisons between trap catches, rain-gauge measurements and outbreaks, but only at district level. A particularly good data set exists for the 1994/95 season, with trap catches and rain gauges indicating periods when armyworm activity was generally high. The details of the prediction were, however, frequently inaccurate, with outbreaks occurring in different weeks and in different districts from those expected from the trap-catch data.

Part of the socio-economic survey involved the assessment of yield losses and benefits derived from control with insecticides. A cost–benefit analysis of the value of armyworm control, and of the value of following a forecast, revealed that when an armyworm infestation occurred, highest returns were obtained when spraying was carried out but returns were less good when there was replanting. This was the case despite frequently poor timing of application, and therefore poor spray efficacy. A useful outcome of the community-based forecasting pilot was that farmers tended to become aware of armyworm infestations in their fields at an earlier stage. The use of community-based forecasts to alert crop monitoring appears to be both feasible and cost-effective.

The socio-economic survey also assessed whether farmers are interested in carrying out their own armyworm forecasting (using a rain gauge and pheromone trap located in the village), and in what ways they are willing to respond to forecasts, either local or national. A forecasting pack in both Kiswahili and English has been produced to accompany training in community forecasting. This includes basic information about armyworms and how they can be forecast; instructions on how to

*Pheromone trap used to obtain catch data for community-based forecasting*

operate the pheromone trap and rain gauge; and how to record and interpret the data in order to make the forecast.

Community-based forecasting, though lacking the larger perspective of a national or international operation, has key advantages. A greater sense of ownership of the process has increased the likelihood that farmers will act on forecasts. The major constraint to armyworm forecasting – that the national forecast usually failed to reach the people who needed it – has been overcome by putting forecast generation in the hands of the people who use it. The national service (PCS) has taken a strong lead in setting up and running the community forecasting plot studies: in the first community-forecasting pilot, the Tanzanian government supplied insecticide spraying equipment for the participating villages and agreed to pay the local costs for a second pilot. These are encouraging signs for further uptake of the approach.

Unlike most migrant pest projects, in community-based forecasting poor farmers are directly involved in forecasting pest outbreaks, and are thus motivated to take appropriate action. This approach to armyworm management proved popular with farmers, and spread by word-of-mouth and by extension officers to neighbouring communities. The forecasting model has been used by the PCS to support district agricultural officers. This project has contributed significantly to the development of PCS as a national resource centre to forecast and promote the control of armyworm.

*Feedback from the stakeholder workshop informed the project's development*

## FURTHER APPLICATION

USAID has funded a series of activities with support from the Ministry of Agriculture to promote and further develop community forecasting, including a further pilot study in Moshi District.

Community-based forecasting is now being linked with community-based control. It is necessary to determine where constraints are likely to exist, for example in areas where armyworm outbreaks are less frequent and so interest in running a trap might not be sustained. In such cases, national forecasting might remain the most appropriate model. Potential also exists to increase the capabilities of the WADI software and develop a generic version that could be used by interested parties in other countries in eastern and southern Africa. A further pilot study has been proposed for Kenya, together with further promotion of community-based forecasting in Tanzania.

# Establishment of satellite ICOSAMP systems and improved migrant pest reporting network

**R8315**

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August 2003–March 2005

The Information Core for Southern African Migrant Pests (ICOSAMP) was established in 2001 to assist with reliable and sustainable cross-border communication and collaboration on migrant pests in the Southern African Development Community (SADC) region. ICOSAMP established an information network that provides up-to-date migrant pest distribution data, enabling decision-makers within the SADC region to forecast impending invasions or outbreaks, and thus reduce the impact of migrant pests on the food security of this semi-arid region. The initial project focused on developing a centralised system. This follow-on project developed the concept of satellite systems – each participating country was provided with computer hardware and software, and a country-specific ICOSAMP system, giving each country collaborator the ability to produce a map and bulletin specific to their own locality. Data input, now the responsibility of each country, was streamlined, and routines were developed for import and export of data between the systems. This project has contributed to building national capacity and pest management strategies in each SADC country, resulting in improved collection of migrant pest distribution data in the region and a valuable, ongoing information database.

## ISSUES

Migrant pests are a major threat to agricultural productivity in the SADC region, annually threatening the livelihood of more than 123 million people. These pests are highly mobile and are able to freely traverse political boundaries, making active cooperation on management and control between neighbouring countries vitally important.

The main migrant pests that threaten food crops are three species of locust [brown locust (*Locustana pardalina*); African migratory locust (*Locusta migratoria migratorioides*); red locust (*Nomadacris septemfasciata*)]; red-billed quelea birds (*Quelea quelea*), see R7967 page 101 and R8314 pages 101 and 103; and African armyworm (*Spodoptera exempta*), see R7954 page 93 and R7966 pages 93 and 96.

The major management technique is preventive control of these pests before they become a serious problem. It is thus important

*The ICOSAMP website, http://icosamp.ecoport.org*

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KIESER, M.E. (2004) *ICOSAMP News Monthly Bulletins.* ARC–Plant Protection Research Institute, Pretoria, South Africa.

website: http://icosamp.ecoport.org

to know the current distribution and scale of infestation, especially in the case of armyworm where the sudden appearance, rapid development and disappearance of the insect call for quick action. Cross-country communication is the key to early warning of impending invasions or outbreaks.

ICOSAMP addressed this problem by establishing an information network in 2001 (R7890), and regularly providing up-to-date migrant pest distribution data to decision-makers in SADC countries. During an ICOSAMP workshop held in South Africa in May 2002, delegates enquired about the possibility of country-specific ICOSAMP systems to assist them with the input and retrieval of data in their own countries, and to allow for the display of primarily country data, but still allow users to view information on an SADC-wide basis. This led to development of the concept of 'satellite' ICOSAMP systems, linked to a central information collection point.

*Calibrating the aircraft prior to spraying operations during the September 2005 training course*

## ACHIEVEMENTS

The ICOSAMP database now contains more than 2500 records of migrant pest control operations undertaken in the SADC region since the inception of the database in 2001. During this project, 450 armyworm, 425 locust and 611 quelea records were added to the database – a significantly higher number than in the first phase of the project. The ICOSAMP gazetteer now contains more than 680 entries.

Twelve SADC country systems were developed (Angola, Botswana, Democratic Republic of Congo (DRC), Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe), along with one system for the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA), and one coordinator's system. This included the construction of country-specific geographic information system (GIS) maps and databases, and provision of new computer hardware and software for each country collaborator. Two systems were translated into Portuguese (Angola and Mozambique), and one into French (DRC). Three User Manuals, one Computer Set-up Manual, and one Co-ordinator's Manual were written. The ICOSAMP website (http://icosamp.ecoport.org) was regularly updated, and 22 ICOSAMP monthly bulletins were disseminated. Personalised and individual training sessions were given to each of the country collaborators in South Africa.

*ICOSAMP workshop participants receiving training*

The objective was to hand over ownership of ICOSAMP at the end of March 2005 to SADC's Food, Agriculture and Natural Resources Directorate, now based in Botswana. However, as SADC is undergoing major restructuring of its offices and staff, and some international donors have withdrawn funding, there is currently no capacity or funding to run ICOSAMP from the SADC offices in Botswana. The current coordinator has agreed to keep ICOSAMP alive under the mantle of the ARC until SADC is able to take over.

As a result of the satellite country systems and the related, improved data input and retrieval, up-to-date migrant pest distribution information has assisted decision-makers in the SADC region to forecast impending pest invasions or outbreaks, thereby reducing the impact of migrant pests on the food security of the region.

## FURTHER APPLICATION

In response to requests from collaborators, the Fourth ICOSAMP Workshop was held in Pretoria (12–16 September 2005), bringing together collaborators from 12 SADC countries. The workshop focused on pest identification, assessment of pest damage, estimation of pest numbers, and various application and control methods.

# Forecasting movements and breeding of the red-billed quelea bird in southern Africa

**R7967**

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Margaret Kieser
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January 2001–March 2003

See R6823, *Perspectives on Pests 1996–2000*, p. 45

## SELECTED PUBLICATIONS AND WEBSITES

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DALLIMER, M., BLACKBURN, C., JONES, P.J. and PEMBERTON, J.M. (2002) Genetic evidence for male biased dispersal in the red-billed quelea *Quelea quelea*. *Molecular Ecology* 11: 529–533.

DALLIMER, M., JONES, P.J., PEMBERTON, J.M. and CHEKE, R.A. (2003) Lack of genetic and plumage differentiation in the red-billed quelea, *Quelea quelea* across a migratory divide in southern Africa. *Molecular Ecology* 12: 345–353.

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SADC Quelea Breeding Forecast website:
http://gisdata.usgs.net/sa_floods/files/region/quel/latest.htm

NRI Quelea latest forecast:
www-web.gre.ac.uk/directory/NRI/quel/Latest.htm

This project sought to improve the livelihoods of small-scale farmers in semi-arid areas of southern Africa where cereal crops are threatened by the red-billed quelea bird (*Quelea quelea lathamii*). A short-term forecasting system, the first of its kind for this pest, was created for use by organisations involved in quelea control, and was improved through a validation process. The system's forecasts were displayed weekly on a dedicated Internet website: 89 out of 91 colonies reported were at sites predicted by the model to have conditions suitable for breeding. No simple method for medium-term forecasts was established, but promising lines for future research were identified. It is likely that very high populations will occur only if there have been high populations in the preceding season. There was a significant positive correlation between numbers of quelea colonies reported and rainfall levels. A desk study of the environmental effects of quelea control showed them to be substantial, and means of minimising them were identified. Uptake of the project's outputs has included handing over the running of the forecasting model to the Southern Africa Development Community (SADC).

## ISSUES

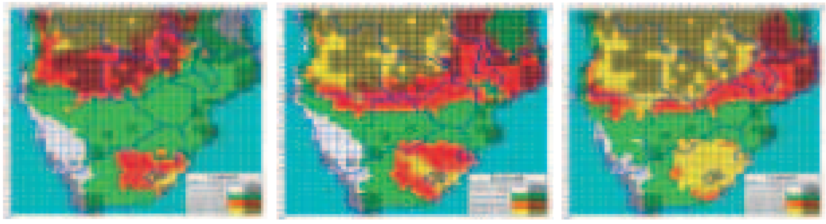
Annual losses to red-billed quelea birds (*Quelea quelea lathamii*) in Africa have been estimated at US$45 million. Populations of quelea threatening subsistence crops are killed with avicides applied either from the ground or

*Quelea quelea*

from the air, or by explosions set off at the bases of roosts or colonies, if they are located soon enough (see R8314, page 103). If quelea were not controlled in South Africa it is estimated that 1 million quelea birds would eat approximately 4 tonnes of wheat per day in one season, equivalent to ZAR100m or US$18m. In some countries, such as Botswana and South Africa, control takes place in most years, but there has been no system to warn where the birds are likely to occur. Even when breeding colonies are located, the speed of the birds' development often means that control teams reach the areas too late, after the juvenile birds which cause most damage have left their nests. This project arose from the need of local institutions responsible for quelea control for a system to forecast where their activities would be needed, and from concerns about the environmental effects of control measures.

As quelea regularly perform long-distance migrations from one affected area or country to another, prediction of where and when they will occur relies on knowledge of their migratory habits in response to the seasonal movements of rain fronts. Rain causes their main food, grass seeds, to germinate at the start of the wet season, forcing birds to migrate away from their dry-season quarters. The birds then undertake further breeding migrations to areas where adequate rainfall will permit them to breed. Thus the patterns of quelea occurrence vary from year to year. The main objective of this project was to devise a model to forecast where and when the birds would be able to breed during a season.

The project was closely linked to the Information Core for Southern



| | Quelea + | Quelea – | Rainfall |
|---|---|---|---|
| Season not started | | | <60 mm |
| Season has started | | | >60 mm in 2 weeks |
| Breeding possible | | | 240 mm in next 6 weeks |
| Breeding less likely | | | 6 more weeks elapsed |

*Sample outputs from the quelea forecasting model for weeks ending (left to right) 22 December 2002, 26 January and 16 February 2003*

African Migrant Pests (ICOSAMP: R7890 and R8315, page 99), which has created a web-based system for information exchange.

## ACHIEVEMENTS

The first model to show where and when quelea can breed in southern Africa was developed, and weekly short-term forecasts were made available on the Internet. The model was developed in consultation with stakeholders during two workshops organised by ICOSAMP. The main model is programmed in Microsoft EXCEL and is based solely upon Meteosat cold-cloud duration data as an estimate of rainfall and knowledge of red-billed quelea breeding biology. A simple geo-stationary earth-orbiting satellite (GOES) precipitation index is used, where temperature below –38°C is presumed to indicate cold cloud that is sufficient for rainfall to occur. Each hour of cold cloud is equated with 3 mm of rainfall. The values for each quarter of a degree are summed and compared with the thresholds detailed, shown above in the legend for the sample outputs. The first forecast was issued on 23 September 2002, and subsequent forecasts have been added to the website at weekly intervals. The model has been successfully validated against 2001–02 data, and similar exercises for other seasons are in progress.

The key relationships were determined between environmental factors, quelea migrations and breeding activities. Detailed observations from two locations in 1995–99 were used to supplement information published over a 34-year period from eastern and southern Africa. The threshold rainfall level required to initiate migration by the birds out of their dry-season quarters was established as 60–70 mm, falling at any time within a two-week period. Information on the subsequent rainfall thresholds is more complicated, as this requires sufficient rainfall to have fallen and sufficient time to have elapsed since the first germination of grass seeds. Project work indicated that breeding could occur if at least six weeks had elapsed after the 60-mm threshold had been exceeded and 240 mm of rain (estimated from durations of cold cloud at –38°C or below) had fallen during this or any subsequent six-week period.

A preliminary analysis was made of the potential for a medium-term quelea seasonal forecasting model based on sea surface temperature data and atmospheric indicators. Although some relationships between quelea activity and rainfall were established (wet conditions during the austral summer months favour increases in quelea populations), the analysis showed that, in contrast to other migrant pests such as the brown locust, it was not possible to use variations in sea surface temperatures to predict quelea upsurges in the medium term. A spin-off from this research was the discovery of significant autocorrelations in the time-series data on quelea. Due to the lack of unequivocal relationships between climate and quelea movements, it was not possible to develop a model for medium-term forecasts, but areas for further study have been identified.

A desk-based assessment was carried out on the environmental impacts of quelea control operations. This is the first review to gather together all published information on the environmental effects of spraying quelea birds with fenthion and the use of explosives against roosts and colonies. The review covers the effects on non-target organisms (especially birds of prey and mammals) and on ecologically sensitive areas.

## FURTHER APPLICATION

The end point of the modelling and processing of large data sets has been quelea distribution maps that are easily interpreted by users, and easily accessed via the Internet. SADC has now taken over the production of quelea forecasts using the models developed, and places forecasts on its Quelea Breeding Forecast website.

A follow-on project (R8314, page 103) was implemented in 2003 to train staff in Botswana on the environmental monitoring of quelea control; to conduct an environmental impact assessment of quelea control in Botswana and develop protocols for this; and to continue to run the quelea forecasting model in conjunction with SADC.

Training from the quelea project was provided at the Pretoria workshop in September 2005 (see page 100), and delegates participated in a lively discussion on drafting a set of standardised protocols for SADC, for monitoring effects of quelea control on non-target organisms.

# Environmental assessment of quelea control and breeding forecasts in southern Africa

**R8314**

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April 2003–March 2005

See R6823, *Perspectives on Pests 1996–2000*, p. 45

This work focused on environmental impact assessments (EIAs) of quelea bird control in southern Africa; continuation of a modelling programme for forecasting quelea breeding opportunities and transfer of the modelling technology to users in Africa; and investigating the potential for community-based control whereby villagers harvest the birds for food. Monitoring of EIAs has been greatly strengthened in Botswana by the training of relevant plant protection officers in the Ministry of Agriculture. Standardised protocols on EIA of quelea control have been developed and disseminated, and parallel running of the southern African quelea bird model has been continued and expanded via the SADC Quelea Breeding Forecast website. Crop protection organisations concerned with the control of quelea will benefit from the development of rational protocols to help minimise adverse effects on the environment, and the results of this work have wider relevance within the southern Africa region.

## ISSUES

A previous project (R7967, see page 101) developed a model to forecast the timing and locations of suitable sites where quelea breeding colonies require control to prevent successful fledging of juveniles.

Birds threatening crops are currently controlled by aerial spraying of their breeding colonies with the avicide fenthion, or by the use of explosives to destroy nocturnal roosts. As there are no standard protocols or codes of practice established within Africa to ensure that environmental damage is minimised, this project aimed to devise such protocols for biodiversity assessment (vertebrates and invertebrates) and evaluation of potential ecological damage. A further objective was to investigate an alternative to sprays and explosions – the harvesting of quelea nestlings as food for people. The most widespread method of harvesting quelea is the collection of nestlings from breeding colonies, which is most productive just before they fledge. Demand for this research was identified through regional discussions, including those with the related Information Core for Southern African Migrant Pests (ICOSAMP) project (see R8315, page 99) with the SADC; and via national authorities including the Ministry of Agriculture of Botswana.

## ACHIEVEMENTS

A week-long training course on EIA of quelea control was run at Sebele, Botswana, in February 2004, and was followed by field-based training. An EIA of the effects of ground-spraying a breeding colony of the red-billed quelea (*Quelea quelea lathamii*) with 4 litres/ha of fenthion, an organophosphate avicide, revealed up to 1.52 mg/kg fenthion in soil samples the day after spraying. Nearly 50% of a treatment dose was still recoverable from soil a week after application.

*Migrant pests seminar, September 2005, South Africa (photo: Margaret Keiser)*

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VENN, J., CHEKE, R.A. and JONES, P.J. (2004) Forecasting breeding opportunities for the red-billed quelea in southern Africa. p. 302. Abstract in: *Proceedings of the 15th International Plant Protection Congress*, Beijing, 11–16 May 2004. Foreign Languages Press, Beijing.

SADC Quelea Breeding Forecast website:
http://gisdata.usgs.net/sa_floods/files/region/quel/latest.htm

NRI Quelea latest forecast:
www-web.gre.ac.uk/directory/NRI/quel/Latest.htm


*Setting explosives in the field*

No differences were found in pre- and post-spray populations of non-target birds estimated by timed bird counts and line-transect methods. However, significant depressions were demonstrated of both acetylcholinesterase and butyrylcholinesterase levels in the blood of target quelea birds and in samples from non-target birds. The high percentage depression (64–88%) found among quelea, and the low cholinesterase values of the non-target species from the sprayed colony, confirm the utility of this assay, conducted with a novel purpose-built field kit, for assessing fenthion poisoning. Such poisoning was probably responsible for the death of a male red-backed shrike (*Lanius collurio*) and the moribund condition of four non-target birds of three other species. Background levels of acetylcholinesterase were recorded in 32 species. This will form the basis of a database against which future post-control assessments can be compared.

An EIA was also conducted of the control of a quelea bird roost with explosives. This involved the detonation of 233 5-litre plastic containers, each filled with 2 litres of diesel and 2 litres of petrol. Apart from a 90% kill of the target birds, three non-target birds and four non-target mammals were also killed, but no significant differences were found in pre- and post-explosion censuses of non-target bird populations. However, analyses of soil samples revealed concentrations up to 9.31 mg/kg of diesel and residues of dibutyl phthalate, presumably phthalates derived from the plastic containers used.

Protocols for the environmental assessment of quelea control were proposed and will be disseminated to SADC countries for consideration for adoption as a regional policy. The protocols include sections on control decisions; safety; EIA decisions; soil sampling for pesticide levels (to be repeated before and after control applications); vegetation sampling; assessment of changes in insect populations; assessment of changes in bird populations; carcass searches; clearing up; and reporting.

The quelea forecasting model for predicting where and when areas within southern Africa become suitable for breeding by red-billed quelea, developed under project R7967, has now been transferred to the Remote Sensing Unit of SADC, and the website has been updated with soil, vegetation and watercourse maps to aid forecasting based on rainfall estimates. The model was also run in parallel throughout the 2003/04 and 2004/05 seasons at www-web.gre.ac.uk/directory/NRI/quel/Latest.htm. A link to both models has been put on the ICOSAMP website (see page 99).

A possible alternative to sprays and explosions – the harvesting of quelea nestlings as food for people – was investigated through interviews conducted with farmers in the region around Bobonong, Botswana. It was confirmed that they prefer quelea breeding colonies to be left uncontrolled so that they can harvest chicks and adult birds to use as food and, in some cases, for sale. Similar practices were recorded in other parts of the country where less systematic and more opportunistic harvesting occurs.

Constraints that hindered more widespread use of the method were identified as:

- lack of transport from villages to quelea colonies
- the existing policy of spraying
- lack of knowledge on ways to preserve the birds
- lack of identifiable markets or means to reach them.

The potential has been demonstrated for reducing the adverse environmental impacts that can arise from the control of quelea birds. The increased environmental awareness of plant protection staff will lead to fewer decisions to apply chemical control – for example, where concentrations of non-target species such as storks are present; or where the local population will undertake their own control by harvesting quelea colonies.

## FURTHER APPLICATION

This work concentrated on Botswana, but has wider relevance within the southern Africa region. The Pretoria workshop in September 2005 (see page 100) disseminated the results more widely, and the quelea forecasting model is being extended to include East Africa. CPP is supporting further work through funding a project on early warning systems and training for improved quelea management in eastern and southern Africa (R8426).

# Biology and control of armoured bush crickets in southern Africa

**R8253**

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December 2002–September 2003

Armoured bush crickets (ABC) are destructive, sporadic pests of smallholder cereal crops in semi-arid areas of southern Africa. This project sought to test and promote strategies for ABC management developed by previous project work in Botswana. The baited trench method of control was tested, although ABC numbers in 2003 were below outbreak levels and findings were not conclusive. Attention was paid to environmental impact: vertebrate scavengers were not attracted to the baited trench, but certain beneficial beetles were often found dead, trapped in the trenches. An economic evaluation suggested that the baited trench method is likely to be cost-effective only in high-yielding years when there is an ABC outbreak, and only for sorghum, not for maize. Field observations of ABC nymphs were undertaken to assess methods for estimating ABC population size well in advance of potential field invasion. Population density on individual bushes was found to be subject to behavioural regulation, with many individuals forced into less-preferred microhabitats at high population density, which means that monitoring ABC population densities on bushes alone is unlikely to be a reliable method of assessing population size. The use of ABC as a dietary supplement for chickens was assessed. Despite the nutritional benefits demonstrated, some farmers apparently are reluctant to eat ABC-fed chickens. However, ABC specialists in Botswana and elsewhere are keen to pursue their use as poultry feed.

## ISSUES

Sorghum and pearl millet are the main subsistence food crops in eastern Botswana and throughout much of southern Africa. Both crops suffer sporadic serious damage due to outbreaks of armoured bush crickets (ABC, known locally as *Setotojane*) – principally *Acanthoplus discoidalis* and *A. speiseri* – which can cause over 30% crop losses in affected areas. Farmers currently have no effective methods of protecting their crops during *Setotojane* outbreaks, and consequently most take no action. Research funded by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Namibia in the 1990s, followed by CPP project R7428, in collaboration with smallholder farmers and the Ministry of Agriculture in Botswana, sought to develop and promote a

*PhD student Pharaoh Mosupi demonstrates how to prepare bait for use against* Setotojane *in the baited trench*

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sustainable IPM strategy against ABC. An effective, acceptable new technique, the baited trench, was developed and refined. Teaspoon quantities (2.5 g) of carbaryl/ bran bait (3 g/kg) applied at 3-m intervals inside a 30-cm-deep trench retained and killed 93% of crickets in on-station trials. Barrier application of fipronil spray (175 g ai/ha) around field plots was field-tested under outbreak conditions and resulted in a 65% reduction in ABC. This project extension aimed to field-test the ABC forecasting system and certain control technologies, including the baited trench; to assess the economics of ABC control; and to assess a potential benefit from ABC – as a diet supplement for poultry.

## ACHIEVEMENTS

Insufficient ABC were present in 2003 for a conclusive evaluation. In each of three valid paired-plot comparisons conducted, mean numbers of ABC present were lower in baited trench-protected plots than in controls, but not significantly so. However, farmers were enthusiastic about the baited trench because they saw that it killed many ABC.

Trench construction is laborious, particularly in heavy soils, and this was a concern for farmers. Further testing of mechanised digging devices was undertaken. Trenches appear to be most effective in more sandy soils; regular minor maintenance is important for trench effectiveness in all soil types.

From an environmental point of view, the baited trench did not attract vertebrate scavengers, but it did result in the death of certain beneficial predatory beetles. Trenches may pose a minor hazard to small livestock.

*Armoured bush cricket* (Setotojane)

A cost–benefit analysis was carried out on the use of the baited trench to protect sorghum and maize from ABC. The high cost of hired labour is a major problem, and costs of constructing a baited trench are frequently greater than benefits from using it. The analysis suggested that the baited trench will be cost-effective only in years of high yield and ABC outbreak, for sorghum. Strategic use of baited trenches in key invasion areas is an option.

Population monitoring of ABC is best conducted in the early morning, when nymphs are sluggish and conspicuous while basking. Counting ABC nymphs is best achieved with minimal disturbance. Population density appears to be limited behaviourally in ABC aggregations, so sampling is needed at several distances from fields in order to gauge the extent of aggregations as well as within-aggregation population density.

*Shoshong choir perform a song (and dance) about the* Setotojane *problem and what they hope to learn today*

A poster for farmers and extension illustrating the different *Setotojane* nymphal stages was produced in Tswana and English. An audience of about 60 attended a symposium on 'Integrated control of armoured bush crickets in southern Africa' at the Entomological Society of Southern Africa's congress in Pretoria (July 2003). Seven talks were presented, followed by a wide-ranging discussion session. An information booklet on ABC biology and control will be printed and distributed via congress delegates to participating countries.

Farmers' chickens kill and eat ABC eagerly. They were found to use a technique for dispatching ABC which circumvents the cricket's chemical defences. A nutritional analysis found that dried ABC are rich in protein, with a crude protein content of 63% (compared with 49% in dried beef). A growth trial was compromised by the shortage of ABC. Chickens provided with dried, mashed ABC as a supplement to commercial feed ate the ABC and grew at least as well as controls. However, some farmers may need convincing that ABC-fed chickens pose no health risk and are tasty.

Owing to the shortage of ABC, the findings of field- and feeding-trial activities were not clear-cut. Nevertheless, important new insights have been obtained about the baited trench method, and the use of ABC as a poultry feed supplement. The successful ABC symposium has disseminated the findings of this and previous work to researchers and extension personnel throughout southern Africa in every country where ABC is an agricultural pest.

## FURTHER APPLICATION

No further work is planned by UK institutes, but DAR plans to continue developing and testing aspects of baited trench and ABC chicken feed in Botswana.

# Promoting potato seed-tuber management for increased ware yields in eastern Uganda

**R8104**

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February 2002–March 2005

Many poor households lack access to healthy seed to grow white (Irish) potatoes in the highlands of eastern Uganda, resulting in poor yields. AT-Uganda Ltd has established a sustainable system of farmer-led potato production that is suitable for planting improved seed in four sub-counties of Kapchorwa District. Production is focused on the implementation of a locally driven and monitored system of quality seed production and marketing. Cycles of multiplication, starting at the level of 20 commercial seed-potato multipliers, moved through to a total of 1410 small-scale farmer-group members who received seed for further multiplication using the small seed-plot system. The commercial multipliers, who formed themselves into a trade association, returned three times the amount of seed received for redistribution and further multiplication by small-scale farmers. An impact survey found that the project has benefited both multipliers and farmers by changing production practices, eating patterns and income sources. The project has taken a holistic approach to training target farmer groups in improved commercial and technical practices, to enable them to exploit the marketing edge of their quality-assured seed potatoes.

## ISSUES

White potato is becoming an important crop in Uganda due to a growing market for chips and crisps. In Uganda, potato production is centred in the highlands close to the Kenyan and Rwandan borders, and is dominated by smallholder farms. Their major constraint is low yields attributed to diseases, and a shortage of disease-free seed.

The earlier LIFE Project, implemented in Kapchorwa District, identified as major constraints the high risk of potato crop failure due to diseases of bacterial wilt disease (*Ralstonia solanacearum*) and blight (*Phytophthora infestans*); availability of healthy seed potato; and knowledge about potato production.

This project aimed to promote farmer-led seed-potato production, focusing on the implementation of locally driven and monitored quality-assured production methods that allow for the traceability of tubers as they move through cycles of multiplication towards delivery to small-scale farmers. This work built on the improved seed-production system developed by CABI Bioscience under project R7858.

*Farmers of Kabale observing development of a seed-plot system*

## ACHIEVEMENTS

The emphasis was on establishing a limited number of viable commercial seed producers, as well as training farmers to maintain their own healthy seed from season to season. Seed for multipliers is then passed over to poor farm households, who multiply the seed further using the small seed-plot system. The project established 20 commercial seed-potato multipliers in Kapchorwa and provided them with training in seed-potato production, disease monitoring and management.

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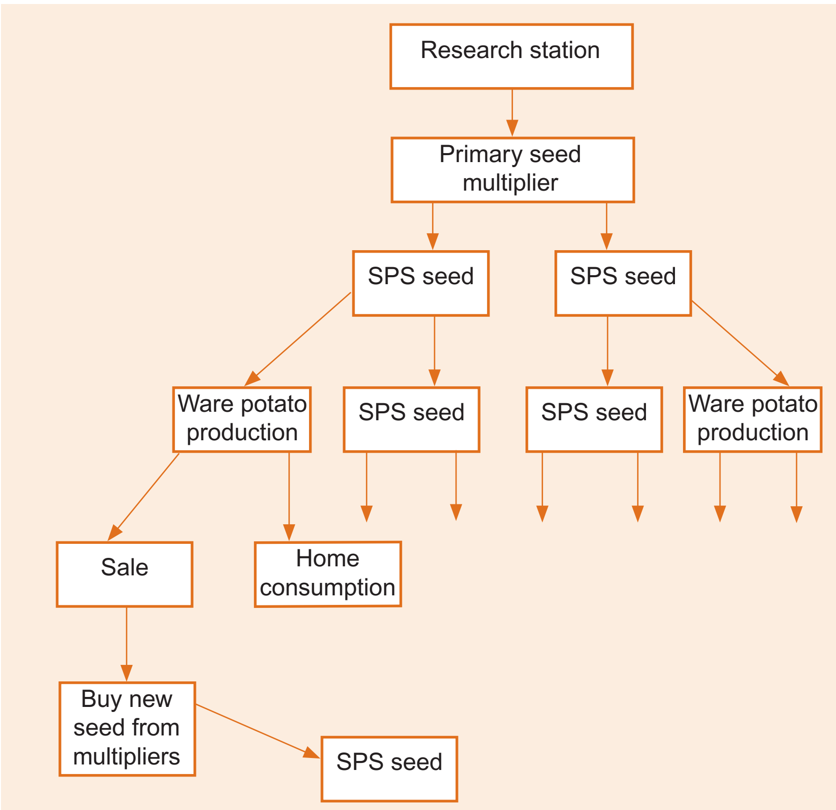
*KASPPA seed potatoes loaded for delivery to beneficiaries*

Twenty primary seed multipliers were identified and established. The project purchased seed (var. Victoria from Kalengyere Research Station) and loaned it to the primary seed multipliers. These seed multipliers formed themselves into the Kapchorwa Seed Potato Producers' Association (KASPPA), which was registered as a local NGO in 2003. KASPPA manages crop best practice, carrying out seed-health monitoring to ensure production of high-quality seed.

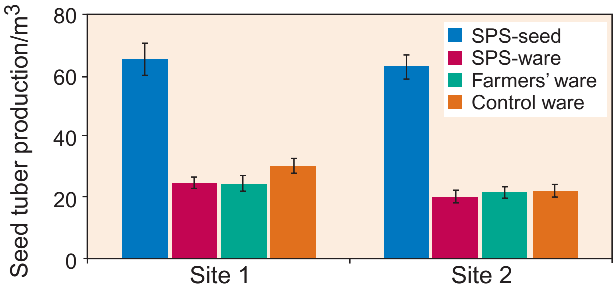
The basic seed obtained from Kalengyere NARO is multiplied by the primary seed multipliers using the ridge/furrow system under strict monitoring, thus assuring seed quality. From the harvested seed, primary multipliers pay back three times the quantity of seed they received. The seed is distributed to numerous small-scale farmers, who multiply it on small plots for their own use, using small tubers less than 30 mm in diameter. This seed-plot technique is suitable for farmers with limited land.




*The seed-potato multiplication system (SPS = seed-plot system)*

All the target farmers and other partner group members have received the improved Victoria seed; they multiply it for one generation, then produce table potatoes. Some of this crop is sold and the money used to purchase clean seed from the primary multipliers.

Seed potato distribution has been tracked successfully by the local leaders (production committees) at group level, and by parish development committees at parish level. Local leaders have been involved in planning, implementing and monitoring seed distribution. As a result, a total of 1200 target farmers received the seed, and additional seed was distributed to 210 members of the partner groups. A total of 1340 bags of




*Seed tuber production per unit area of land at two sites under the seed-plot system (SPS-seed) and traditional ridge/furrow ware cultivations: using seed derived from SPS (SPS-ware); farmers' saved seed from ware production (Farmers' ware); and Tigoni Research Station (Control ware)*

seed were distributed to small seed-plot multipliers.

The 20 primary seed multipliers, four extension staff, four field assistants, 80 production committees, members of eight parish development committees and more than 1400 farmers were trained in best practices for potato production/multiplication, disease identification/management, and storage. Three thousand copies of a *Farmers' Guide on Potato Production* were produced by AT-Uganda and distributed to farmers. Crop best practices were developed for KASPPA on crop production, disease monitoring/management, and storage.

Two artisans were trained to construct diffused light stores, and constructed 20 stores in collaboration with seed multipliers. The project contributed 50% of the cost and the multipliers contributed the balance.

A repayment rate of 98% was realised from the seed multipliers. The 2% default arose when some of the tubers were rejected for seed due to bacterial wilt infection.

To support production by the primary potato multipliers, the project developed management tools for crop management that aim to provide a best-practice, quality-assured, identity-preserved pathway of potato multiplication. The main management tool is the 'crop history sheet', which provides a written record of management practices and pest status at the field level.

In addition, as a response to the destructiveness of bacterial wilt in potato, an on-farm, post-harvest incubation test for the interception of infected seed, which can be implemented by farmers, has been tested with promising results. KASPPA members have managed to keep levels of bacterial wilt below 1% in their crops.

*Diffused light store for controlled sprouting*

The results of an impact survey carried out in September 2004 indicate that more land has been put under cultivation by beneficiaries since the project started. Land allocated to potato production has increased, and potato is now ranked second in area by multipliers, and third by beneficiaries. A clear benefit was seen for household income. Potato has gained preference as a staple food among beneficiaries and multipliers, with current consumption once or twice a week – previously the project potatoes were rarely eaten. Beneficiaries are increasingly adopting technologies such as improved varieties and regular field inspections, while multipliers now adopt all the technologies. Adoption of potato-growing since 2002 among non-beneficiaries is more marked among the neighbours of beneficiaries than is seen in non-beneficiary villages and parishes.

## FURTHER APPLICATION

Farmers have a clear incentive to adopt and maintain the improved practices promoted by the project, as they provide added value through growing quality-assured seed potatoes that attract a premium profit margin. However, some form of independent certification or approval mechanism might be required to back this up. Even then, the sustainability of such improvements will be subject to the fragile economic environment and unexpected droughts that can undermine farmers' and consumers' abilities to pay premium prices for improved crop inputs. As a result of the strong foundation laid by this project, AT-Uganda is now well placed to expand the project's impact to new communities, to strengthen KASPPA, and to facilitate market links, especially for ware potatoes.

Planned activities being funded under a nine-month extension to the project (R8435) include:

- KASPPA strategic planning
- selection of new sub-counties, parishes and groups
- training of new groups/sub-county marketing associations
- establishing demonstration sites, organising field days
- setting up marketing committees, market promotion
- establishing simple potato stores
- end-of-season evaluation
- final external impact assessment.

# Public–private partnerships to develop viruses as bioinsecticides for Ghana and Benin

R7960

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January 2001–March 2004

See R6615, *Perspectives on Pests 1996–2000*, p. 53

Brassicas, particularly cabbage, are key cash crops for peri-urban vegetable farmers in West Africa – but larvae of the diamondback moth are a severe constraint to production. The appearance of widespread resistance to commonly used insecticides is driving farmers to spray their crops more and more frequently to control diamondback moth, while others abandon their fields or give up brassica cultivation altogether. This project worked through partnerships between government departments, the private sector and research scientists to evaluate *Plutella xylostella* granulovirus (*Plxy*GV) for control of diamondback moth larvae on brassica crops, and to examine the constraints, opportunities and implementation routes for biopesticides in Ghana and Benin. *Plxy*GV imported from Kenya proved highly virulent towards diamondback moth larvae from Benin. In participatory trials, growers in Benin found that crop yield and value in virus-treated plots exceeded those in control and farmer-practice plots. In Ghana, *Plxy*GV efficacy was acknowledged but was more critically received. Wide-scale adoption of *Plxy*GV in Ghana and Benin is unlikely in the short-to-medium term without economic incentives or donor support. However, through informed debate, local stakeholders in the biopesticide industry are now better informed than prior to the project, and as a consequence the prospects for biopesticides in the region are brighter.

*Peri-urban vegetables in Cotonou, Benin*

## ISSUES

Abuse and misuse of insecticides is common in Africa, and although the consumption of pesticides in the continent represents less than 5% of the global total, misuse is disproportionately high. The increasingly important peri-urban sector accounts for ever-larger volumes of insecticide consumption in which products, dose and application frequency are not well regulated. Insecticides imported for use in export crops spill over into the peri-urban sector for which the products are not approved. In West Africa, lepidopteran pests attacking a wide range of peri-urban crops are the targets of frequent applications of chemical insecticides. Such chemicals are associated with the familiar problems of environmental pollution and human contamination, rising costs and resistance development.

With the high value of brassica crops, the larva of the diamondback moth (*Plutella xylostella*) is among the most serious pests in peri-urban agriculture. Farmers all claim pesticides are required for diamondback moth control and many have expressed interest in testing biopesticides.

While there has been substantial technical progress in the development of biopesticides, their uptake has been limited. The early stages of biopesticide R&D are often undertaken in the public sector using public finance, but many potential biopesticide products fail to go beyond the laboratory or field-trial stage. Commercialisation is an important implementation pathway for

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*Good quality cabbages treated with PxGV, Lokossa, Benin*

biopesticides, and failure to engage the private sector and a lack of market data are factors contributing to poor biopesticide uptake.

The project proposed partnerships with the private sector to motivate and encourage commercial enterprises to establish production of the viral insecticides, by first demonstrating that these products have the potential to be manufactured and sold for a profit.

## ACHIEVEMENTS

*Plutella xylostella* granulovirus (*Px*GV) was transferred from Kenya to Benin under a Material Transfer Agreement, and tested in a series of laboratory and field trials. Links to the East African cluster of vegetable IPM projects (R8297, page 116 and R8341, page 122) facilitated negotiations.

Laboratory assays demonstrated that Kenyan *Px*GV was significantly more virulent towards *P. xylostella* larvae from Benin than towards those from Kenya. Laboratory assays also showed that *Px*GV could be transmitted horizontally at high larval densities, and that it could move from the soil to plant surfaces in sufficient quantity to cause infection. Trials on treated potted plants exposed to sunlight showed that the half-life of *Px*GV was less than four hours. On-station field trials demonstrated that *Px*GV was as effective in reducing larval numbers as acephate, a standard insecticide used by brassica growers, and also as effective as the bacterial biopesticide *Bacillus thuringiensis* (*Bt*). Daily application of a 1/10th dose of *Plxy*GV-Nya01 improved yields, as did use of a proprietary UV protectant.

Fifty cabbage growers in each country participated in farmer-led trials and farmer field school training in the use of *Px*GV. Yields in *Px*GV-treated plots exceeded those in control and farmer-practice plots. Growers were encouraged by the results, but disappointed that the product was not commercially available when the trials finished.

In Benin, there are no public or private companies with experience in producing and distributing biopesticides. *Bt*-based products come in across the borders, but are not registered for use. Small-scale pesticide distributors are interested in biopesticides if there is demand, but they are concerned about efficacy. Among pesticide importers, few are interested in biopesticide distribution to vegetable growers because of poor demand, but those that did express an interest would want to be sole representatives. Distributors would like to see growers more aware of biopesticides in order to guarantee the market. Farmer training sessions and demonstration plots are seen as important mechanisms for promoting biopesticides. Farmers and distributors would prefer a liquid formulation sold in (re-usable) plastic bottles (pesticide containers are routinely re-used for other purposes), and a product that can be applied at watering to avoid the need for application equipment. Products packaged in small quantities would be preferred because of farmers' small plot sizes and lack of cash. Three further factors significantly affect a farmer's willingness to buy a biopesticide: perceived ineffectiveness of current chemical pesticides; access to extension for technical advice on pest control; and perceived capacity of a new biopesticide to control new pests. Many farmers in Benin would be willing to test a new biopesticide against *P. xylostella*, although lack of training means that few understand the difference between biological and synthetic pesticides.

In Ghana, *Bt*-based products are widely used. Active promotion of IPM by the Government of Ghana has given vegetable growers greater awareness of alternative pest control methods. Farmers' willingness to buy biopesticides is determined principally by their education, access to extension services, and previous experience in the use of DiPel (*Bt*). Opportunities for the promotion of biopesticides in Ghana are the ongoing IPM strategy; rising concern over the safety of chemical pesticides; and implementation of EU maximum residue limits on fresh produce. Some of the constraints to be overcome are farmers' preference for fast-acting, broad-spectrum pesticides; the wide range of pests that have to be controlled; inadequate distribution networks and inappropriate storage facilities, especially at retail level; and lack of a regulatory framework for registration, importation, production and use of biopesticides. Products based on *Bt* are the only commercial biopesticides available in Ghana and Benin. Botanical pesticides are widely but locally used, and either produced *in situ* or bought from local cooperatives and NGOs.

Due to the differing degree of IPM engagement in the two countries, adoption of a biopesticide may have greater success in Ghana than in Benin. Investment in a national vegetable IPM and extension training programme would improve the likelihood of successful adoption in Benin.

*Farmers in Benin learning to scout for cabbage pests and beneficial insects*

A Pan-African workshop on bio-pesticide registration, sponsored by Virginia Tech, USAID, DFID and IITA, was attended by 40 representatives of stakeholder organisations from 15 countries across Africa. The workshop made significant contributions to the development of biopesticide registration guidelines in the Comité Permanent Inter Etats de Lutte Contre la Sécheresse au Sahel (CILSS) and countries in eastern Africa.

## FURTHER APPLICATION

The biopesticide industry is driven largely by consumer, retailer and government pressure on growers to reduce dependence on synthetic pesticides. In Africa, while there is a general trend towards promoting IPM, pressure is not yet adequate in all markets to drive the adoption of alternatives to synthetic pesticides. Global trends suggest that biopesticides tend to address high-value niche markets, therefore the poor may not derive direct or immediate benefits. The project operated in an environment that did not facilitate biopesticide development; relevant legislation was, and still is absent; private sector manufacturing capacity is weak or non-existent; credit is expensive; and knowledge is limited. Current thinking assumes that implementation of biopesticides will not be achieved, hence outputs of the current project will not be utilised unless additional effort is made to remove these barriers. However, under certain circumstances, for example the development of an export vegetable market, it is conceivable that market forces alone could stimulate the creation of a biopesticide industry. While cabbage growers who tested *Px*GV appreciated its efficacy, there currently exists no imperative that would drive sustainable adoption of such a biopesticide, even after the removal of barriers.

A further phase of this work aims to follow up with:

- workshops for regulatory authorities in West Africa on the introduction of biopesticide product-specific regulations, including provision of model regulations
- a market analysis of biopesticides in West Africa from a commercial perspective
- an analysis to identify potential commercial partners and countries for a biopesticide-manufacturing plant
- funding of a team to champion biopesticide production and uptake in West Africa.

# Sustainable approaches for management of root-knot nematodes on vegetables in Kenya

**R8296**

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April 2003–March 2005

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Root-knot nematodes (*Meloidogyne* spp.) are significant pests of vegetable and flower crops, although the pests themselves are invisible to farmers. The current demands of the European market for greatly reduced pesticide use have led to a need for alternative control methods to meet increasingly stringent requirements on exports. This project aimed to verify and promote sustainable approaches to the management of root-knot nematodes through the use of microorganisms, cultural techniques and plant resistance. Through research participation, smallholders have been acquainted with root-knot nematodes and methods of control. The novelty has been the inclusion of naturally occurring biological control organisms within the cropping system preferred by (or acceptable to) farmers. This will become an accepted practice when the national regulatory authority approves the use of biopesticides; when organisations have the capability to mass produce these products at an acceptable price; and when there are appropriate channels to deliver them to the smallholder grower community. Progress has been achieved with each of these stages, which will help to ensure long-term benefit to all sectors of the Kenyan vegetable-producing community.

## ISSUES

Root-knot nematodes (*Meloidogyne* spp.) have a worldwide distribution, and are pests of more than 2000 plant species. They are significant pests of vegetable and flower crops. The nematodes cause gall formation on roots, leading to stunted plant growth and low yields; they also disfigure root stem tubers, reducing their market value. Root-knot nematodes are a concern to many smallholders and commercial producers involved in intensive vegetable production in Kenya. Although not all smallholders will recognise nematodes as a production constraint, up to 20% of vegetable producers use nematicides when growing tomatoes, as currently this is the only control strategy available.

Nematodes are difficult to manage. They are soil-dwelling animals, too small to see without a microscope, and cause symptoms on the root system that can be recognised only when a plant is lifted from the soil. For this reason smallholders, who are reluctant to dig up plants, usually overlook the presence of nematodes and attribute above-ground symptoms (small fruit, poor growth, yellow foliage, wilting during hot weather) to other biotic or abiotic constraints. This often results in the use of inappropriate chemicals. This project aimed to familiarise smallholders with nematodes – the desire to adopt biological and cultural control strategies can only result from an understanding of what nematodes are, and how they damage crops.

*Quality standards are increasingly important to outgrowers who supply vegetables to commercial markets within and outside Kenya*

All sectors of the vegetable industry are keen to adopt production methods based on low-pesticide


*Galls on roots of tomato (above); juvenile nematode infected with spores of a biocontrol agent (inset)*

regimes. In Kenya, commercial export producers are attempting to meet European Union standards and codes of practice through the initiative on harmonisation of pesticide use of the Europe–Africa–Caribbean–Pacific Liaison Committee (COLEACP) and the EurepGAP Standards, an initiative of retailers belonging to the Euro-Retailer Produce Working Group (EUREP), a partnership of agricultural producers and their retail customers aiming to meet accepted standards and procedures for the global certification of Good Agricultural Practices (GAP): www.eurep.org.

Because of links between the commercial export sector and independent growers through the outgrower system (smallholders who supply vegetables to commercial markets within and outside Kenya), the new pest management technologies will also be introduced to the wider constituency of smallholder producers. In addition, locally based organisations and associations such as the Kenya Institute of Organic Farming (KIOF) represent a locally driven initiative of concerned farmers committed to organic production.

Within this changing scene of improving systems of vegetable production, root-knot nematodes are one pest for which a sustainable management system needs to be developed. The opportunities have been strengthened through collaboration with Dudutech (Kenya) Ltd, which has implemented a range of biological control programmes, including mass production of the biocontrol agents *Pochonia chlamydosporia* (a fungus) and *Pasteuria penetrans* (a bacterium) for managing root-knot nematodes.

Building on technology developed by previous CPP projects (R6611, R7472), Dudutech Ltd (through project R8218, April 2002–March 2004) sought to develop a protocol by which *P. penetrans* can be mass-produced on a commercial scale to enable its widespread use by farmers within a broader IPM system. Two *Pasteuria* spp. isolates were obtained by the commercial producer, and stable production systems developed for the control agents, their hosts (root-knot nematode) and the vegetable crops they depend on. These production system components were optimised to establish a reliable and predictable method, and then scaled up. At the start of the project, biological control agents had no specific regulations for their registration and use as crop protection products. Through collaboration with a commercial partner, project R8218 contributed significantly to the development of a Kenyan registration system specific to biopesticide and biological control crop protection agents. Dudutech Ltd is committed to further commercial development and scaling up of production of this biological control agent.

It has recently established a 70-m polytunnel for propagation of host plants, root-knot nematode and *Pasteuria* spp. at Naivasha, and has employed two full-time technical staff dedicated to commercial production of this biological control agent. In addition, through successful collaboration between the National Center of Animal and Plant Health in Cuba and Dudutech, *Pochonia* production technology has been transferred to Kenya. Dudutech has refined the production of *P. chlamydosporia* and is producing 40 kg of formulated product per week; this can be scaled up to 100 kg/week when required.

Biocontrol agents of root-knot nematodes can be difficult to manipulate because they are location-specific in terms of the pathogenicity of the natural pathogens and their interactions with abiotic and biotic soil factors. Whilst overcoming the technical challenges, smallholders must be advised that the processes of biological control may take several crops to take effect. The routes for promotion of a nematode-control strategy based on biological control agents will be through demonstrations and the more highly supervised production systems of the commercial export producers and their outgrowers.

## ACHIEVEMENTS

Methods of scaling up the *in vivo* system of mass-producing *P. penetrans* are being investigated by Dudutech, but as yet no consistent process has been developed because of the dependence on uniformly warm temperatures, and on large supplies of nematode hosts on which to produce the parasite. Spore yields of 3.26–5.6 × $10^6$ per g of dried tomato root have been achieved.

On-farm trials were set up in Mwea and Kibirigwi, areas known for tomato production for both commercial and home consumption. The trials involved the use of *P. penetrans* and *P. chlamydosporia*, crop rotation, and tomato varieties with resistance to root-knot nematodes. The on-farm trials were participatory and involved farmers practising organic and inorganic farming methods. The first category consisted of farmers from Maragua practising organic farming under rainfed conditions. The second category was inorganic farmers from Kibirigwi practising production under rainfed and irrigated conditions, and farmers from Mwea growing tomatoes under irrigation.

*Evaluation of resistant tomato varieties: above, Cal J (susceptible); below, Monyala (resistant)*

Farmers' perceptions and preferences showed that a 'new' variety with root-knot nematode resistance (Monyala) was ranked best (of four), including the standard cultivar Cal J, which is nematode-susceptible.

When *P. chlamydosporia* was applied through a drip system, spores were not delivered evenly along the line of the drippers. This could be a technical problem relating to formulation, because of the size of the chlamydospores. Distribution of spores of another biocontrol fungus, *Paecilomyces lilacinus,* through such a system is better, probably because spores of this fungus are smaller and consistent in size.

This work is moving towards an environmentally safe strategy for managing root-knot nematodes which need not include hazardous chemicals. Biocontrol 'products' are now available for wider use, and will be of benefit to poorer farmers growing nematode-susceptible crops. Commercial growers who grow crops on contract to exporting companies will also benefit. Amendments to the pesticide legislation to include those defined as 'biopesticides', such as *P. chlamydosporia* and *P. penetrans*, have been drafted and await final legislative ratification. This will enable companies to produce and market these products.

## FURTHER APPLICATION

Biological control agents for root-knot nematodes are now available in Kenya, but until the pesticide legislation is ratified by Parliament, these 'products' can be used only on farms owned by Homegrown, the parent company of Dudutech. However, Dudutech is now in a position to produce sufficient product for sale to other commercial concerns, and to the smallholder outgrowers who supply vegetables to commercial markets within and outside Kenya. These products and the associated knowledge will be made more widely available through organisations representing the export sector (such as the Fresh Produce Exporters Association of Kenya) and organic growers (such as KIOF).

The results of this research were made available to participants in the Gatsby Nematology Capacity Building Project for East Africa, which continues for five years from April 2005. Associated research projects will include further studies on the deployment of biological control agents for root-knot nematodes.

# Development of private service providers for the horticultural industry in Kenya

**R8297**

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April 2003–March 2005

See R6616, *Perspectives on Pests 1996–2000*, p. 50

In Kenya, smallholder participation in exporting horticultural crops is threatened by a lack of efficient extension services. To ensure the continued participation of smallholder producers in this sub-sector, a pilot study was conducted to establish private service provision of advice, input supply and plant protection, to help farmers comply with changing rules and regulations. Fifteen private service providers were trained in IPM, with the aim of reducing pesticide use and improving produce quality, food safety, and human and environmental health. The course graduates are now either self-employed or contracted by fresh produce-exporting companies. The graduates have helped to prepare small-scale producers and outgrower farmers' groups for EurepGAP certification. At policy level, awareness of the plight of small-scale farmers with respect to new food standards has prompted some of the standard-setters to review the requirements, making them more accessible to end-users. At producer level, farmers are now better informed about the EurepGAP Standard, and the majority are in the process of implementing some of the requirements.

## ISSUES

The horticultural export industry in Kenya, and in East Africa, has faced increasing difficulties in complying with the ever-more demanding requirements of European markets. Increased intensity in both local market production and export-oriented systems has led to a 'chemical spiral', with rising production costs and decreasing productivity. This is associated with a high risk to human health, especially for farm labourers – many of them women and children – and with environmental pollution.

An efficient extension service with the ability to create awareness among smallholder farmers about health and environmental risks, market demands, and how to comply with these, is not in place anywhere in the region. In consequence, many smallholder farmers are exposed to the risks of excessive pesticide use, and in the case of export producers, are being squeezed out of the industry. Many of the established horticultural exporters in Kenya are over-burdened by providing the basic services necessary to keep their outgrowers in production.

Previous work (R6616, R7403) was aimed mainly at farmers producing vegetables for the local market. A cluster of projects based in Kenya (R8296, page 113 and R8341,

*Training of trainers: horticultural outgrowers were assisted with the new EurepGAP Standard*

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DOBSON, H. and COOPER, J. (2003) *Training Guide for Private Sector Service Providers, Modules on Safe and Effective Use of Pesticides*. Natural Resources Institute, University of Greenwich, Chatham, UK.

ICIPE (2004) *EurepGAP – What smallholder producers of fruits and vegetables must do to access markets in European Union*. Technology Transfer Unit-ICIPE/Business Services Market Development Project, Kenya.

ICIPE (2004) *EurepGAP standard for small scale farmers of fresh fruits and vegetables to the European market.* ICIPE/Business Services Market Development Project, Kenya.

page 122) has aimed at reducing reliance on pesticides and finding alternative pest-management strategies for vegetable crops that are environmentally friendly and affordable. The ICIPE Horticulture Programme has also developed IPM options for French beans, tomatoes, brassicas and okra production for Kenya. All these needed to be disseminated appropriately to end-users, particularly smallholder producers. In recent years ICIPE, with Deutsche Gesellchaft für Technische Zusammenarbeit (GTZ) Germany, has been involved in conducting training-of-trainers courses for the horticultural export industry. The promotion of validated technologies is complemented by training in business management and extension skills.

In Kenya, export of fresh produce is basically private sector-driven, so knowledge about marketing and quality control is in the domain of the export companies. It was therefore decided to consult reputable Kenyan horticultural exporters for information on how best to organise and formulate the training curriculum.

## ACHIEVEMENTS

Business models for private service providers to horticultural producers were developed. Appropriate training modules and a curriculum were produced, and 15 private service providers graduated from the training. These are now either self-employed or working with fresh produce-exporting companies to prepare small-scale producers for EurepGAP certification. [EurepGAP is an initiative of retailers belonging to the Euro-Retailer Produce Working Group (Eurep), a partnership of agricultural producers and their retail customers aiming to meet accepted standards and procedures for the global certification of Good Agricultural Practices (GAP): www.eurep.org]

Awareness was created about the effects of the supply-chain requirements (including EurepGAP), and access to the export markets


*From the ICIPE poster: 'What smallholder producers of fruits and vegetables must do to access markets in European Union'*

by small-scale producers, for a wide range of stakeholders at national and international policy levels. Some standard-setters and donor agencies have recognised the fact that small-scale producers are at risk of being excluded from export markets due to stringent food standard requirements. As a result, some policy changes have already taken place.

- EurepGAP is committed to assist Kenya in developing 'Kenya-GAP', benchmarked on the EurepGAP Standard, which will bring the services closer to end-users.
- Kenya will have a representative at the EurepGAP Committee.
- DFID is committed to co-financing field-testing of the *EurepGAP Smallholder Quality Manual* in collaboration with GTZ. This will be a starting point for Kenya to create its own quality manual by adopting content according to the local production situation, with a view to preparing farmers for EurepGAP certification.
- Some fresh produce-exporting companies [InduFarm (K), the Fresh Produce Exporters Association of Kenya, East African Growers, Kenya Horticulture Exporters, Greenlands Agroproducers and Myner Exporters] are working with outgrowers' groups to meet the EurepGAP Standard.
- The Ministry of Agriculture, (Horticulture Department) has commissioned a review of the EurepGAP Kenya training programme.

One outgrowers' group in Kerugoya District was certified EurepGAP-compliant in December 2004 by Africert Ltd, a local certification body accredited to EurepGAP. Three other groups were close to full EurepGAP certification but experienced difficulties in the final stages; lessons from this experience are being addressed by the project extension.

## FURTHER APPLICATION

This project was a pilot for the privatisation of government services in Africa, and was therefore a learning platform. In Kenya the proposal was in line with the National Agriculture and Livestock Extension Programme Implementation Framework, which supports the National Agricultural Extension Policy. Lessons from this pilot will lead to broader moves towards privatisation in areas where private sources of payment for services, as in horticulture, are available.

Under a one-year project extension (R8438), a quality manual for smallholders is being developed and tested in collaboration with GTZ. The lessons from the pilot and extension phases are being documented and will form part of a final report for wider use in East Africa.

# Promotion of quality vegetable seed in Kenya

**R8312**

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April 2003–March 2005

It has been estimated that vegetable production provides nutrition, income and employment for more than four million poor people in Kenya. To increase yields of vegetable crops, high-quality seed is critical. This work focused on kale seed production in the Kenyan highlands. With inputs from farmers, the project addressed issues affecting the quality of seed produced, especially seed health problems, to improve future practices and quality. Seed-testing procedures for kale have been developed in collaboration with the regulatory body KEPHIS, and local personnel have received training. The project has developed and validated a suitable model for a sustainable kale seed-multiplication system that enables smallholders to produce healthy, good quality seed of an acceptable market value, harvesting kale leaves only up to flowering (half-pick model) and then harvesting the seed – in preference to 'no-pick' and 'full-pick' models, where seed harvests were lower. The reliability of these results is reinforced by the obvious enthusiasm of participating farmers, who moved ahead rapidly to achieve the outputs. The possibility of farmer groups establishing a commercial seed business has been investigated. Seven superior, preferred kale lines have been selected for further development as improved varieties that should have a lasting impact on kale production in Kenya.

## ISSUES

Market gardening and horticultural enterprises represent a significant source of income for many small- to medium-scale growers in Kenya. Brassicas are an important part of the diet of Kenyans, especially in low-income groups. In addition, brassicas (kale and cabbage) and tomatoes are the most important vegetables for the domestic economy, being grown by over 90% of smallholders. Kale (*Brassica oleracea*) is cultivated both for home consumption and commercial sale. However, much of the currently available vegetable seed is expensive, imported and of poor quality. There are substantial opportunities to increase yields through improved, adapted varieties, high-quality and affordable seed, and enhanced knowledge and production skills.

The main issues associated with seed quality are:

- identity of the seed (is it the stated variety?)
- contamination with other species/varieties of seed
- germination rate (affected by transport conditions, shelf life, dumping of poor-quality seed)
- availability of the desired variety (seed control practices may result in a monopoly)
- seed health
- the cost and value of seed
- whether appropriate packet sizes are available.

*Kale plant used for seed selection*

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SPENCE, N.J. *et al.* (2006) Characterisation of *Turnip mosaic virus* (TuMV) and *Cauliflower mosaic virus* (CaMV) isolates from Kenya and their economic impact on cabbage and kale production. *Plant Pathology* (in press).

Most vegetable seeds sold in rural markets are of poor quality because the seeds are from a mixture of varieties, and disease aspects are not taken into account when seeds are collected.

Previous research on seed production in Kenya (R7571) has generated great demand from farmers, who need to be able to distinguish good seed from bad in the local market. There is a clear opportunity for farmers in Kinale District (part of peri-urban Nairobi, Central Kenya) to brand and market quality kale seed of known origin. As these local kales are landraces, they should not be subject to legislation.

KARI has an existing Seed Unit for developing local seed-multiplication schemes. Virus infections and black rot (caused by the bacterium *Xanthomonas campestris* pv. *campestris*, *Xcc*) are the diseases of most concern to kale- and cabbage-growers. Although the deployment of resistance is widely seen as the most promising approach to disease control, extensive testing of a worldwide brassica germplasm collection (at Warwick HRI, Wellesbourne) has not yet found any effective resistance to races 1 and 4 in *B. oleracea*. Knowledge of which races are present locally is needed for an effective control strategy based on resistance. Such a strategy is long term; in the short term, control of black rot disease should focus on using clean seed and minimising the risk of carrying over the disease in crop debris.

## ACHIEVEMENTS

A socio-economic survey examined farmers' perceptions of seed, and identified potential opportunities for farmers to produce and market their own, improved-quality seed. The availability, distribution and supply of existing brassica seed in Kenya was surveyed, and a seed inventory produced. This provided the information needed for entry into the commercial seed sector.

Using a questionnaire circulated by the Ministry of Agriculture and data collected by KEPHIS, information was collected on how far farmer-produced seed from Kinale travels. Several districts/divisions (such as Nyeri and Embu) were found to be growing Kinale kale at the start of the project.

*Sowing seed with farmers in Kinale*

A project development meeting held with agriculture staff and extension officers in Kinale provided information on how farmers who multiply kale seed are organised, and identified kale farmers and farmer groups to work with. As a result, Lari Division extension officers joined the project, making many visits to farmer groups with the project team.

The potential for establishing and registering a commercial seed business in Kinale was examined. Information was gathered from farmers and seed companies such as Lagrotech, and constraints and opportunities were identified. A recommended plan was drawn up for consideration by farmers, to show them the steps involved in progressing to a commercial seed business.

The health of existing kale seed with regard to fungi, bacteria and viruses was determined. The bacterial black rot pathogen *Xcc* was present, and a range of fungi were also isolated: *Alternaria* spp. were the most common. The worst affected seed came from farmers, demonstrating the importance of promoting seed health to these producers.

A strategy for sustainable and viable production of improved-quality kale seed was developed through participatory on-farm trials in Kinale with key farmers/farmer groups. This involved three on-farm trials with participatory farmer groups, and one on-station trial at Njabini to be used for demonstrations.

A suitable model for a sustainable kale seed-multiplication system, which enables smallholders to produce healthy, good quality seed of an acceptable market value, has been identified. In the preferred model, farmers pick kale leaves for comsumption up to flowering (half-pick model) and then harvest the seed. This was preferable to the 'no-pick' and 'full-pick' models, where seed harvests were lower. The model has been validated and established on land volunteered by three farmer groups, directly represented by over 50 farming families in three key seed-production areas in Kinale.

Monthly participatory activities were established with farmer groups. These included sowing seed beds; transplanting seedlings; examining plants at regular intervals during the trial; participatory budgeting of inputs; and harvesting of leaves and seed.

Promotional materials encouraging good seed-multiplication practice, and emphasising the value of producing/purchasing good quality vegetable seed, have been developed and disseminated to more than 1000 smallholder farmers, NGOs and micro-entrepreneurs through KARI, extension services, NGOs and via other pathways in Kenya.

The incidence and prevalence of *Xcc* in seed stocks currently used for production were examined with the aim of improving quality assurance. Infection was found in several imported seed lots. The survival of *Xcc* in brassica crop debris was examined, and the results demonstrate the importance of crop debris as a source of primary inoculum. This information will be used as a basis to develop practical strategies for sustainable management of black rot in brassicas.

Local seed-testing capability for *Xcc* has been improved. Key personnel from KEPHIS Plant Health Quarantine Station were trained at Warwick HRI for three weeks in methods for seed testing/pathotyping of *Xcc* according to the latest methods of the International Seed Testing Association. A reciprocal visit was made to the laboratories at KEPHIS and KARI's National Agricultural Research Laboratory (NARL), providing practical training for appropriate staff.

Kinale farmers expressed a strong interest in multiplying and marketing seed of improved health and quality. In close collaboration with KEPHIS inspectors, using international guidelines of the Union Internationale pour la Protection des Obtentions Vegetales (UPOV), significant progress has been made in the analysis of Kinale kale as a variety. A crucial achievement by farmers and researchers was the selection and evaluation of seven lines from a trial of 24 Kinale kale lines, grown at the KARI research station, Njabini. These very impressive lines will be in demand by farmers in the future.

Outputs from the project will help farmers to produce their vegetable crops (for consumption and sale) in a safe, more effective and economic way. Benefits will include improved nutrition for whole families, better cash returns from higher yields of better quality produce, and empowerment through agricultural knowledge that will help farmers make informed choices on other cropping options.

Sound strategies have been promoted to farmers to improve the quality of the kale leaves and seed produced, to their benefit and also to the benefit of other farmers who buy Kinale kale seed, and consumers who eat Kinale kale leaves. In addition, the project has established a sustainable kale seed-multiplication system that will enable smallholders to produce good quality, healthy seed with an acceptable market value, and has developed a marketing strategy that will benefit farmers directly. Increased production of higher-quality kale leaves and seed will increase farm incomes, improve nutrition for consumers, and contribute to enhanced livelihoods for participating households. It should also attract other kale seed farmers to adopt the improved practices.

## FURTHER APPLICATION

A follow-up project (R8439) is now in progress to facilitate the registration and release process of new varieties of Kinale kale, while also supporting existing informal farmer-to-farmer distribution under the regulation of KEPHIS

*Kinale kales lines are unusually tall (most >2 m high)*

*A very heavy pod-producing Kinale kale plant that needs two workers to support its pods, at KARI Njabini Sub-Station*

and in collaboration with KARI and NGOs. Specific outputs will be the continued evaluation of new kale seed lines in trials for distinctiveness, uniformity and stability, using selfed seeds of each of four kale lines selected by farmers. A portion of these seeds will be submitted to the KEPHIS National Variety Release Committee, which is made up of all seed companies and organisations who intend to enter their various crop varieties to be tested in the National Performance Trial. These trials will be conducted at several locations across the country, where the varieties are tested against many other similar varieties entered for the National Performance Trial by various seed companies and organisations. Participatory multiplication trials of the new kale lines will be conducted at Njabini, KARI-NARL, and KARI stations at Thika, Kisumu and Kakamega to obtain data on their performance, which may be used while defending the lines during the KEPHIS National Variety Release Committee meeting in March 2006. Preparatory seed multiplication will also be carried out to ensure that sufficiently large amounts will be available when a variety is ready for official release. The genetic stability of kale populations will be assessed, and opportunities for *in situ* and *ex situ* conservation of kale diversity in Kinale will be considered, in consultation with the International Plant Genetic Resources Institute (IPGRI) in Nairobi.

Following on from this project's work on black rot, the incidence of seedborne pathogens of kale in seed-production systems will be monitored. The release process for new kale seed lines will be initiated through registration with a registered seed business, including consultation over legal matters. After seed growers have produced kale seed that meets all the field KEPHIS certification standards, seed will be bought by the seed company, and will be subjected to all post-harvest KEPHIS viability and other quality tests. Seed will then be processed, dressed, packaged as required by seed laws, and marketed within Kenya and beyond. Marketing Kinale Kale seed as a brand to make it well known to farmers will be achieved through several forms of advertising (posters, brochures, radio, on-farm demonstrations, agricultural shows). Lagrotech Seed Company already works with over 400 seed stockists all over the country, including marketing through the Kenya Farmers' Association, which has branches all over the country. Kinale Kale seed will be marketed through these outlets.

Sustainable seed-production technologies (management of a seed crop, seed-multiplication methods, harvesting, germination, seed processing) will continue to be promoted through on-farm participatory demonstration plots, and via production and dissemination of publicity materials.

There is potential to promote the key lessons learned to other groups involved in vegetable seed production in sub-Saharan Africa, and to seed companies that rely on farmer-produced kale seed.

# Promoting the adoption of IPM in vegetable production

**R8341**

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Louise Labuschange, Henry Wainwright
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September 2003–March 2005

See R6616, R6615, *Perspectives on Pests 1996–2000*, pp. 50–55

Horticulture provides employment for around two million people in Kenya, but there is scope for expansion and improvement. Many horticultural crops are susceptible to pests and diseases, and farmers often rely on chemical sprays to maintain and increase supply to a growing urban population. They want easy, rapid and reliable crop protection, and a common perception is that pesticides are the modern (and hence desirable) solution for successful farming. Previous research by CPP and other projects has shown that a mix of traditional and newer control techniques, important in IPM, can reduce reliance on pesticides and improve sustainability. These methods are knowledge-intensive, but to date farmers have received little objective and scientifically sound information, advice and training on how to minimise the use of pesticides and how to use them sustainably. This project aimed to develop training capacity and to pilot an effective system for disseminating information to trainers and farmers, to enable them to use IPM to grow safe and healthy crops in a profitable and sustainable way. Information was incorporated into a series of training aids comprising a *Manual for Trainers*, a comprehensive training kit and various targeted dissemination resources. These kits provided the foundation for a two-level course design that enabled the project to train 16 specially chosen trainers, who initially trained over 500 farmers, with the aim of improving the quality and production levels of vegetables in Kenya.

## ISSUES

Horticultural crops – both for local consumption and for export – are important in Kenya. They are recognised for their health and nutritional benefits, and provide cash income. One-tenth of vegetables in Kenya are grown for export. The total area under horticultural crops is estimated at 245,920 hectares, of which approximately 100,000 hectares are under vegetable production.

Production of vegetables in Kenya, especially for the expanding domestic market, is still limited by major pest and disease problems, and a lack of information and knowledge of improved technologies to address these major constraints. The majority of smallholder vegetable farmers rely heavily on spraying pesticides to reduce the damage caused by pests and diseases. These farmers pay little attention to cultural pest management methods or the potential role of natural enemies. Pesticides are marketed aggressively, but there is little objective, appropriate and scientifically sound information, advice and training on how to minimise their use or how to use them sustainably. The cost of pesticides absorbs a significant proportion of farmers' income, but without information on cultural and biological technologies, farmers have few alternatives. The mixture of traditional and newer techniques that comprise IPM can reduce reliance on pesticides and improve sustainability.

Further challenges exist for growers who export crops to Europe, where many pesticides are being withdrawn, as standards governing production and handling of fresh produce become stricter. Fewer pesticides, and very low permitted residue levels, present farmers with no choice but to adapt to more rational use of carefully chosen pesticides, integrated with use of alternative pest management strategies. This pressure for change coincided with the aims of the project and probably made stakeholders much more open to new ideas.

## SELECTED PUBLICATIONS

DOBSON, H.M., MATTHEWS, G.A., OLEMBO, S., BALEGUEL, P. and WILES, T.L. (2004) Application challenges for small-scale African farmers: a training initiative in Cameroon. *International Advances in Pesticide Application. Aspects of Applied Biology* 71: 385–392.

DOBSON, H.M., COOPER, J.F., AGUDAH, R. and WAINWRIGHT, H. (2005) *A Manual for Trainers – Promoting Integrated Pest Management*. NRI, Chatham, UK.

DOBSON, H.M., COOPER, J.F., AGUDAH, R., WAINWRIGHT, H. and MWAMPEMBWA, G.A. (2004) Calendar 2005 – Pest Management for Smallholder Farmers. NRI, Chatham, UK.

This training and dissemination-based project aimed to wean growers away from existing practices that include over-use of pesticides, overdosing and wrong choices of product, leading to poor efficacy.

## ACHIEVEMENTS

This project was a collaboration with the Real IPM Company (Kenya). It was one of three projects commissioned by the CPP in 2003 (along with R8297, page 116 and R8299, page 128) to initiate dissemination of outputs from previous research (including projects R6146, R6615, R6616, R6799 and R7403), and to ensure that the beneficial impact of this work is maximised.

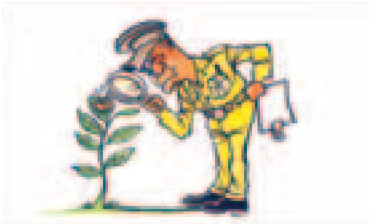
This project focused on developing the tools, skilled personnel and promotion techniques to enable others to continue with sustainable IPM promotion. New vegetable IPM instructor's resource kits were developed and used to train IPM instructors. The kit is based on a training manual covering curricula at two levels: a training-of-trainers course, and farmer training materials for use by IPM instructors in conjunction with existing dissemination resources such as handbooks and posters. The training manual contains guidance on course planning and delivery of sessions, practical training exercises, interactive games, and materials that can be used in courses or issued as handouts. It concentrates on pest management in tomato, brassicas and green beans. The materials, all housed in a strong case, provide a tool to help plan and execute training. Kits include posters, books, a calendar, calculators, spray equipment and a hand lens, in addition to the manual. The usefulness of the individual components was rated very highly at a workshop that took place after the instructors' training.

Several supplementary dissemination resource materials were produced, including two posters translated into Kiswahili and an IPM calendar for 2005. The cartoons for the calendar (see examples, right) were drawn by Gado, the cartoonist from the *Kenya Daily Nation*, based on themes developed by the project team. Key messages were identified by the project team, then ideas for visualising these messages were developed by the artist in a collaborative exercise. Both languages were included in the calendar. The planned print run of 1000 was doubled, which enabled the resources to be widely distributed to stakeholders (including projects of CAB International and the International Centre of Insect Physiology and Ecology), as well as horticultural and export companies, outgrowers, and organisations conducting training in the horticultural industry. All the farmers (over 500) trained by the project received an IPM calendar and at least two posters.

After the manual had been drafted, a team of 16 would-be vegetable IPM instructors were given a detailed six-day intensive course in IPM – this team then went on to carry out individual farmers' courses. On the training-of-trainers course these instructors, selected from the private, government and NGO sectors, had the opportunity to give mock farmer-training lessons, before presenting their own courses within six weeks of the end of the primary course.

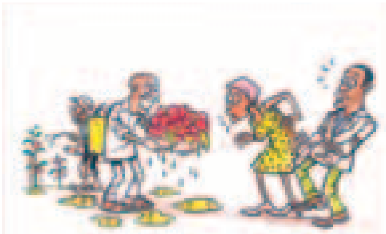
This team of instructors then trained over 500 farmers in how to adopt vegetable IPM techniques. Their trainees consisted of outgrower farmers and some small-scale domestic vegetable growers. One-third of the trainers' courses were observed by the project team. Getting farmers to 'do' rather than merely listen was stressed on the primary training-of-trainers course and, as a consequence, the secondary courses were carried out in a far more participatory way than the traditional lecturing style commonly used with farmers.

Feedback and comments were captured throughout the project.



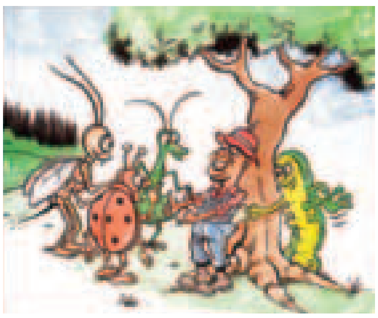
*Scouting is detective work – inspect the crop very carefully before deciding whether to spray*

*Don't use more spray than you need*



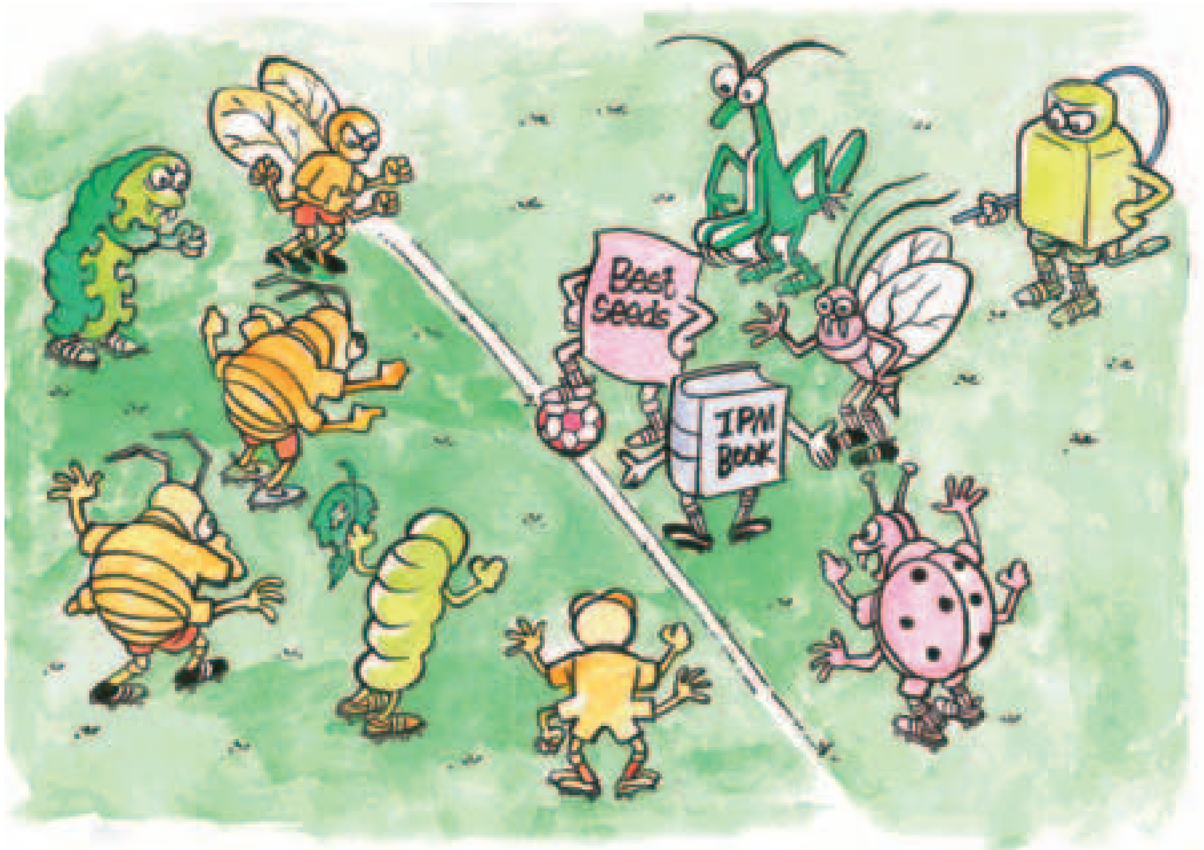
*Produce may be dangerous if harvested before the pre-harvest interval*


*Flowering plants provide food for farmers' friends and attract them*



*Pests can rob you, but some insects are friends*

*Cartoons from the 2005 Calendar of Integrated Pest Management (reproduced courtesy of Gado)*




*'IPM team stars' (reproduced courtesy of Gado)*

Information was gathered anonymously from participants after both the training-of-trainers and farmers' courses. The usefulness of training kit components was also rated. This information helped to formulate the objectives of a one-year project extension.

Several impact-assessment visits were made in March 2005 to farmers who had attended IPM courses run by project-trained instructors. The aim was not a systematic survey, more an informal appraisal of the success of the training programme to date and an opportunity to gather information to inform the design and approach of the follow-on phase. Responses were very positive, with farmers stating that the training and materials provided were very useful. An indicator of impact and retention was that farmers could describe several of the calendar cartoons and explain the serious message without a copy in front of them. A direct indicator of adoption was that many farmers said that, since receiving the training, they scouted rather than calendar-sprayed their crops, and now realised how much money they had been wasting.

An assessment was made of the likelihood of continuing beneficial impact from the training given within different sectors. For example, while the access, geographical reach and sustainability of agrochemical input agents are high, the integrity of the information may be compromised by the sales motives of the individual. In contrast, the access and geographical reach of NGOs may be lower, but the 'fit' with their mission is better and the long-term beneficial impact is likely to be higher.

In terms of numbers trained, the 500 or so farmers whom the project reached are only a small proportion of the production base, which comprises many thousands. However, the training manual and other resources produced by the team will provide a major resource in the longer term, and the numbers trained will eventually far exceed the 16 trainers and several hundred farmers who have already been reached.

This project has contributed to the capacity to respond to the national and international groundswell of food safety, human safety and environmental protection measures that are increasingly affecting the horticultural industry. It has done so by helping growers to overcome the important limiting factor – the ability to control pests safely and sustainably.

## FURTHER APPLICATION

There is now an opportunity to broaden the reach of this dissemination by developing materials to support the information that can be used by farmers. One way of reaching very large numbers of farmers is to use 'farmer trainers' – trained farmers who go on to deliver peer-to-peer training and awareness-raising in the community. An extension to the project (R8417) aims to provide resources for this group so that they can multiply the impact of the parent project more effectively.

# Linking demand for and supply of agricultural information in Uganda

**R8281**
**Joint-funded with Livestock Production Programme**

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*Centro Internacional de Agricultura Tropical, Uganda*

Chris Garforth
*University of Reading, UK*

February 2003–March 2005

## SELECTED PUBLICATIONS

AFRICA 2000 NETWORK (2005) *Integrated Pest Management for Groundnut Production: A User Guide.* Africa 2000 Network, Uganda.

AGWARU, G., MATSIKO, F. and DELVE, R. (2004) Assessing approaches for dissemination of research information to farmers within their livelihood situations in Tororo District, Uganda. *Ugandan Journal of Agricultural Sciences* 9: 265–270.

BAMARU, J. (2005) *Farmers' Guide to Integrated Pest Management – Pigeon peas.* Arua Local Government Offices, Uganda.

BUTTERWORTH, R.R., ADOLPH, B. and POUND, B. (2004) Experiences of packaging research outputs into extension materials. *Ugandan Journal of Agricultural Sciences* 9: 111–118.

POUND, B., ADOLPH, B. and MANZI, J. (2004) Piloting an adaptive research process to address farmer's information gaps. *Ugandan Journal of Agricultural Sciences* 9: 137–146.

Limited communications, and a lack of specific focus of information generated by both public and private sectors, mean that smallholder farmers in Uganda receive little in the way of relevant extension information and materials. Working with government agencies (particularly NAADS and NARO), MUK, private-sector service providers, NGOs and farmer groups, this project has made significant contributions to the integration of smallholder demand for agricultural technologies with the supply of information from a variety of sources, including DFID research programmes in eastern Africa. Through project-sponsored MSc studies, the limitations of the present NAADS demand-assessment system have been highlighted and recommendations for their improvement formulated. Major progress has been made in making information sources more aware of the information needs of end-users, and a national Standing Committee is now in place to oversee the content of research outputs. A format for dissemination materials, based on project recommendations, has been adopted by the national agricultural research systems. This format includes social and economic factors, enabling location-specific selection of options by farmers. A comprehensive survey of private service providers in two districts has identified information constraints that compromise their ability to serve farmers adequately, and recommendations have been made to NAADS to address the situation.

## ISSUES

Smallholder farmers in Uganda have limited access to anything but the most locally generated information, and depend mostly on family and friends. Many, especially the poor, are illiterate and have little access to TV or newspapers. Some have radios, but they may not be able to interpret the general information provided for their specific circumstances. There is very limited contact with the extension services, and less with researchers.

Few dissemination materials are available (even to extension staff). Private service providers also lack up-to-date information that is relevant to local situations, and are often not under pressure to seek the best information available. Extension materials are usually technology-focused. They are rarely adapted for specific districts, and lack much of the information farmers need to make informed choices. Demand for the project was identified from NAADS,

*Wealth ranking as a prelude to assessing the adequacy of farmer demand processes for different types of farmer in Arua and Tororo districts of Uganda*

NARO and farmer groups. The NAADS Secretariat was particularly interested in components that would enable private service providers to operate more effectively. Meetings with senior NAADS and NARO staff, and the outcomes of an inception workshop held with a range of stakeholders in Kampala, in November 2002, demonstrated clearly that there is a major problem with the availability of research information in easily accessed formats and the relevance of its content to smallholder farmers.

This project aimed to improve smallholder farmers' access to agricultural information relevant to their needs. The two main components of access are the information demand and information supply processes. The project identified constraints for both, and addressed some of these issues.

## ACHIEVEMENTS

The project was fortunate to work during a time of considerable dynamism in NAADS and the national agricultural research systems. A project workshop brought directors of NAADS and NARO and senior university staff together with NAADS district staff, district farmer forum chairmen, private service providers and international researchers, to discuss institutional links constraining the flow of information between stakeholders. A large number of constraints were recognised. Of these, four (review of service-provider contracts to encourage empowerment of farmers through information; information packaging; horizontal links; and facilitating knowledge-seeking) were chosen for further exploration with relevant institutions.

The first aim was to develop demand-discovery mechanisms that identify demand from a much more inclusive range of intermediate and end-users than is currently the practice. An MSc study assessed the NAADS demand-identification process, based on the following criteria:

- inclusion of the poor
- participation of farmers in decision-making
- transparency of the process
- alignment between farmers' and NAADS criteria
- inclusion of cross-cutting issues.

Recommendations made to NAADS and others as a result of the findings were:

- continuous farmer–farmer mobilisation
- use of local structures such as elders and local councils
- flexible ways to pay membership fees
- affirmative action for marginalised farmers and youth
- enterprises that do not require large cash investments and have low risk, to attract poorer farmers
- review NAADS criteria to consider household food security needs, and value addition of traditional food crops such as cassava
- sufficient information provided for farmers during the planning process, via training
- longer interaction time with new groups
- terms of reference for service provision that address cross-cutting issues including natural resources management and marketing of agricultural produce.

Improved tools and mechanisms were developed to support the supply of appropriate information and technologies. Private service providers in two districts were profiled, and their information use, quality control and needs were identified. Recommendations were made to NAADS for improving their access to, and use of, information in order to provide better services to farmers.

Very poor households were less than proportionally represented in farmer groups compared with the general population. All wealth categories had limited access to market information. Overall, the average wealth category had relatively more access to information, while very poor farmers are not well catered for in technology dissemination. Farmer groups are composed of different types of farmer, and projects find it difficult to cater for this heterogeneity. Overall, information demands were highest for pest and disease control, soil improvement, marketing and availability of inputs. There is no clear mechanism for feedback of information from farmers to researchers.

The project has assisted in the establishment of the Ugandan Working Group on the Coordination of Development and Dissemination of Information Materials for Service Providers and Farmers. This has recommended that NARO and NAADS should establish a joint Standing Committee to coordinate and oversee quality assurance of agricultural information materials for service providers and end-users. The Factsheet format developed by the project, in collaboration with COARD, is to be adopted officially and promoted by NARO and other institutions.

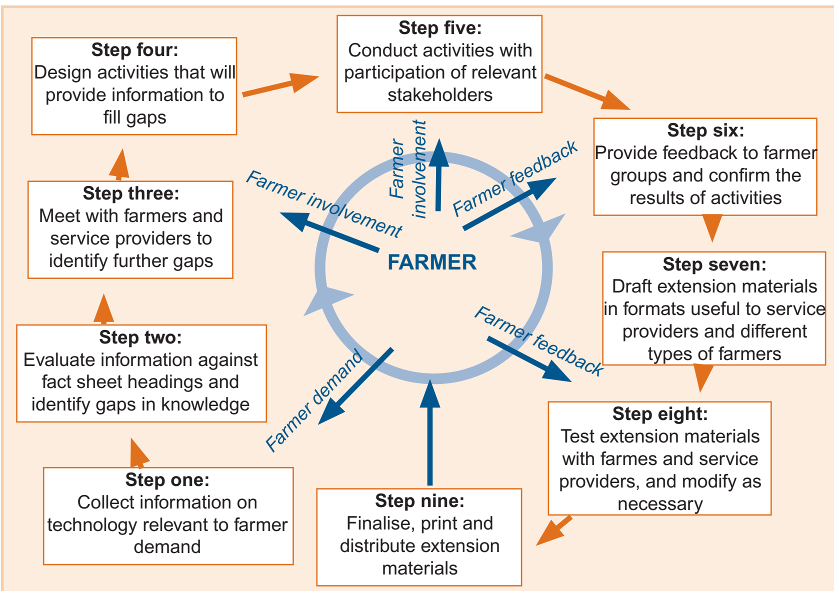
A number of options, appropriate to local conditions and responding to farmers' needs, were identified and tested. A novel, demand-driven, multi-agency, farmer-participatory, adaptive research process, that has as its main outcome the provision of locally relevant dissemination materials for service providers and farmers, was tested using three technology topics – goat de-worming; IPM of food legumes; and draught animal power (DAP). The process was well received, although initially its radical nature was not well understood. Stakeholders liked features such as inter-institutional learning, farmer involvement, and the development of dissemination materials. Two of the three technology topics were successful in reaching the stage of producing dissemination materials. The third (goat de-worming) tested the use of *Mucuna* trichomes as a botanical substitute for chemical de-wormers. The results were inconclusive, although the botanical agent does appear to have been effective against cestodes (for explanation of terms see Glossary, page vii). IPM manuals for pigeonpea and groundnut were produced by the Ugandan team as a result of the adaptive research process, and draft dissemination materials have been produced by the DAP team (including cost–benefit analyses, guidelines for social organisation in group use of DAP, and the advantages and disadvantages of DAP under different conditions); see R7401, page 54.

Institutional mechanisms were developed for integrating supply and demand for information. As a result of project work, NAADS is considering various aspects of service provider contracts, including incentives and ways for service providers to improve the advice they give to farmers. Working groups have been formed to improve information packaging. Further possibilities include commissioning private providers to package research results, and sponsoring electronic learning and exchange platforms between partners.

*Banner of the project's* Linking *newsletter (www.naads.or.ug/publications.php)*

The Linking project has influenced policy and strategy by providing a stream of information to research and extension institutions in Uganda through the *Linking* newsletter; a Ugandan project manager post; meetings with senior Ugandan staff; presentations of research findings to stakeholder workshops; and via formal papers at national and international workshops and conferences.

The Linking project has contributed to the reduction of poverty in Uganda through improving the agricultural information available to poor farmers by providing mechanisms for disadvantaged groups to have a voice in setting priorities; improving the information-demand identification process at grassroots level; improving the supply of relevant production and post-harvest information; supporting the commercialisation of food and non-food farm products to improve incomes and markets; and facilitating institutional links that address breaks or weaknesses in the information demand and supply flow. It has contributed to policy-setting by NAADS and NARO on apsects of understanding and supplying the knowledge needs of farmers and intermediate information users.



*Draft nine-step process for adaptive testing of technologies*

## FURTHER APPLICATION

A project extension continued work on recommendations, in collaboration with NAADS, to modify current demand processes so that natural resources management issues are considered more fully by farmer groups at the enterprise-selection stage and when terms of reference for extension services are drawn up. The strengths and weaknesses, replicability and cost-effectiveness of the adaptive research process piloted by the first phase of the Linking project were critically assessed by NARO, MUK, NAADS and local government staff, and recommendations were developed for its incorporation into the Uganda R&D system.

Excellent links have been developed with key institutions in both public and NGO sectors. There have been effective efforts to help associated DFID projects utilise the opportunities for improving information flow developed under this project. The strong links to NAADS, NARO and local government provide a good base for institutionalisation of the work, and the inclusion of focused MSc studies has added a further valuable capacity-building element.

The methodologies developed are useful and applicable over a range of countries, and this work will be used to help guide a similar farmer-oriented effort in Tanzania.

# Accelerated uptake and impact of CPP research outputs in Kenya

**R8299**

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July 2003–March 2005

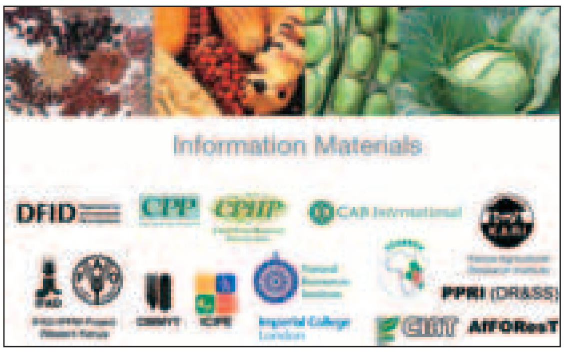
The CPP has produced a large array of new technologies on weeds, diseases, insects and rodents, some of which are based on a material product, while others are knowledge-based. Making new technologies available to farmers who need them is an essential step in turning good research into impact on livelihoods, but one that has not always received the attention it merits. This project focused directly on that step, aiming to accelerate the uptake of CPP research outputs in Kenya. Research outputs were promoted to farmers in western Kenya through a network of farmer field schools (FFS) already established by an ongoing project funded by IFAD. The process was demand-led: farmers specified the crops they wished to work on each season, and indicated the constraints experienced in each crop. Technologies were collated from CPP and other research programmes, and presented to the FFS facilitators who then introduced them to the FFS. Farmers chose the technologies to try out in their own and/or group-managed plots. FFS members were also surveyed for their preferences on the content and format of dissemination materials. Farmers' evaluations indicated the positive impacts of the technologies they tested: over 80% felt their food security had been improved, and marketed surplus was also increased, contributing to improved farm incomes.

## ISSUES

The uptake of research results and new technologies has traditionally been a major bottleneck in turning good research into improved livelihoods for the poor. One reason for this is that scientists frequently feel their new findings or technologies need to be refined before being ready for uptake. In some cases this is true – but often farmers are able to use and adapt new information through their own experimentation and experience as part of a dynamic, ongoing process. Once this capacity is recognised, the opportunities and potential for uptake are greatly increased, at the same time providing opportunities for valuable feedback to scientists.

This is the basis of farmer field schools (FFS), an approach originally devised for IPM in rice in south-east Asia, and adapted for use in Africa. One such project (IFAD-funded through the UN Food and Agriculture Organization, FAO) now has tens of thousands of farmers involved in integrated pest and production management (IPPM) in East Africa.

In recent years, CPP research on pests has produced an array of new knowledge about weeds, diseases, insects and rodents, published in many papers and other dissemination materials. Some of this work is ongoing and requires further development, but much useful knowledge is already




*The project's dissemination CD was sponsored by a number of organisations*

## SELECTED PUBLICATIONS

CAB INTERNATIONAL (2005) *IPPM Information on Sweet Potato, Beans, Maize, Sorghum, Kale and Groundnut*. CAB International Africa Regional Centre, Nairobi, Kenya (CD-ROM).

INTERNATIONAL INSTITUTE OF BIOLOGICAL CONTROL (2004) Helpful dudus in the shamba. Wadudu marafiki mashambani. CAB International Africa Regional Centre, Nairobi, Kenya (leaflet in English and Kiswahili).

KARI (2004) Production of kales (*sukuma wiki*) and onions using bucket drip irrigation. CAB International Africa Regional Centre, Nairobi, Kenya (leaflet).

*Sorghum, sweet potato and maize were among the crops on which farmers needed information*

available. Some technologies are a material product with potential for commercialisation, but many CPP outputs are knowledge-based with little potential for commercial uptake. These are the outputs on which this project focused. While CPP has funded much valuable research in IPM, other research has also been undertaken, including work by KARI supported by DFID and others; Dutch-funded work at the International Centre of Insect Physiology and Ecology (ICIPE) on stem borers; and Rockefeller-funded work by KARI and others on soil fertility – thus the project was not confined to promoting only CPP research outputs. Farmers do not compartmentalise their problems in the way scientists do, so the project's strategy for promoting research outputs was to address farmers' production needs through a demand-driven approach.

## ACHIEVEMENTS

The results from socio-economic work in western Kenya revealed high demand for information on sweet potato, beans, maize, sorghum, groundnut and kale production. Many farmers felt that they had limited access to new IPPM technologies as a result of weak research–extension–farmer links. They felt that the limited technologies accessible to them were not always relevant to their local conditions, either because they were tested in different locations, or because farmers were not consulted about their relevance. A wide range of IPPM research outputs was collated from different research institutes and validated by over 3500 farmers through FFS, and results were shared with about 2000 other farmers during field school open days. Farmers' participation in validating the technologies resulted in increased farmers' confidence to make informed decisions about which technologies to apply. Farmers have also adapted the technologies to suit their local production system.

New knowledge has been acquired on uptake pathways for research outputs, and dissemination materials have been produced and distributed containing information on topics identified as relevant by the farmers themselves. As a result of the project, 50 intermediary organisations working with farmers now have access to a wide range of dissemination materials on six key crops, for continued use in their work.

Participants in FFS were consulted on their preferences for the content and format of dissemination materials. Relevant existing materials were collated and adapted and modified where necessary, and new materials were created. Twenty-two dissemination products were reproduced and disseminated to intermediary organisations as well as through the FFS. One of the products was a CD-ROM containing the source files for all the materials, allowing intermediaries to develop or reproduce further materials to their own specifications.

Surveys and farmer evaluations indicated positive impacts of the technologies tested by farmers. The greatest improvements were seen in maize and kale. Farmers reported that income from maize production increased by 30%, and there was an increase in maize yield of up to 50%. Income from kale production increased by 20% and yields increased by 10%. As maize is a staple food crop in the area, food self-sufficiency and food security have improved due to adoption of the technologies.

Participatory extension and technology delivery has met FFS members' demand for knowledge on their chosen crops, produced for consumption and for the local market, while avoiding high investment in external inputs. Increased marketed surplus was also reported in maize and kale, contributing to improved farm incomes. Pesticide use did not increase, but fertiliser use increased on all crops except sweet potato, where none was used. For all crops, farmers reported an improvement in the content and timeliness of the crop production information they had received as a result of the project.

## FURTHER APPLICATION

Further work is needed to make available specific inputs in connection with the technologies that farmers found beneficial and wish to continue using. Further copies of the CD-ROM produced by this project will be disseminated to intermediary organisations in Kenya, Uganda, Tanzania and other countries with similar production systems. During this project demand was also expressed for tomato IPPM technologies, and this will be addressed by an extension to the project (R8454).

# Ecologically based, sustainable rodent-control strategies in South Africa

**R8190**

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April 2002–March 2005

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Rodents are a long-standing problem throughout the world, and have a major effect on the rural poor through consuming and contaminating stored food, damaging field crops, transmitting diseases, and degrading buildings. This project aimed to develop sustainable strategies for rodent management in rural communities of South Africa. All the key stakeholders were involved from the outset, from farmers and those delivering rodent-management products and services, to those developing and implementing policies for rodenticide use. Outcomes include changes in the policy for training government officers engaged in pest control, and inputs into university courses. The project linked up effectively with the EU's public health RatZooMan project to address the cross-cutting public health issues. Surveys and analyses carried out included the role of the private sector – especially the control product dealerships and companies offering control services. As a result, a local company has become involved in manufacturing efficient and affordable traps. In addition, rodent taxonomy has benefited from the discovery of a species previously unknown in Africa, as well as the first recorded occurrence of another species in South Africa. Information obtained on the trends of seasonal abundance and spatial distribution of the major rodent species, and possible inter-specific competition, is also new for South Africa, and of wider interest in Africa.

## ISSUES

In Africa, rodents are by far the greatest vertebrate pest problem. Management of rodents has focused on conventional methods, mainly the use of rodenticides. These methods are supported by government, especially to contain outbreaks. However, conventional control methods have remained largely ineffective.

Building on previous work in Zimbabwe, Mozambique and South Africa (R6685, R7372, R7777), this project aimed to provide poor households and small-scale farming communities with sustainable and environmentally benign management of rodent pests. This formed part of a broader strategy to improve the food security of resource-poor and small-scale farmers and their communities through increased availability and improved quality of maize, which is the staple food of households in Limpopo Province.

## ACHIEVEMENTS

By working with target communities as well as the traditional rodent-management service providers (environmental health officers, agricultural extensionists and the commercial pest control industry), the project developed novel methods and strategies that were researched and evaluated for their cost–benefits and ability to deal effectively with the rodent pest problems experienced by rural agricultural communities. This research was done in collaboration between UK and South African scientists, as well as the key stakeholders (both end-users and service providers). The project worked in close collaboration with the EU-funded Rodent Zoonosis Management (RatZooMan) public health project.

Responses to farmer questionnaires indicated that rodents affect many aspects of people's lives, ranging from being bitten by rodents at night, to losses in food stores and damage to clothing. A number of respondents indicated that they had been bitten by rats. Rat bites can carry diseases; preliminary results from the RatZooMan project indicate that leptospirosis was found in 30% and toxoplasmosis in 43% of the

*Housing in Mapate reviewed for rodent access: left, brick and tile-roofed (improved) house with reduced access to rodents, but the open kitchen makes it easy for rodents to get into food preparation areas. Centre, this building provides easier access and harbourage for rodents compared with the neater homestead (right).*

rat samples tested in one farming community. Although rodent damage to field crops can be as high as 20% at harvest, farmers rarely ascribe damage to rodents – farming communities tend to perceive them as household pests. Rodenticides are used, but in a haphazard way which renders them ineffective. This encourages the illegal use of highly dangerous, acute agrochemical poisons such as aldicarb. Although farmers were generally aware about rodent control tools such as rodenticides and traps, knowledge on their correct and effective use was lacking.

Studies were carried out on reducing rodent populations through intensive trapping. Trap success from break-back traps in and around 80 households and four crop fields, over a continuous period of 18 months, demonstrated to both the communities and government extension workers the effectiveness of trapping, as well as the efficacy of the break-back trap. Severe drought conditions during the assessment period prevented reliable results on rodent damage to crops in storage. Damage to maize in crop fields without trapping ranged from 10 to 28%.

The species composition of rodents caught inside dwellings differed between the four villages studied in Limpopo Province. *Rattus rattus* was the dominant species, comprising 55–71% of rodents caught in three villages in the warm and dry southern regions; *Mastomys natalensis* replaced *R. rattus* in the village situated in the humid, sub-tropical northern region. Field catches were mainly of *Mastomys* species. The project made a significant contribution towards mapping rodent distribution in Limpopo Province, which is not well documented, including *Mastomys coucha*, a plague carrier that is an important link between sylvatic plague foci and the domestic environment. Of appreciable scientific value was the discovery of the oriental rat, *Rattus tanezumi*, a first recording of the species in Africa; and the grooved-toothed mouse, *Pelomys fallax*, a first recording in South Africa.

Results from a market survey indicated that most of the known rodenticide brands were available from retailers, but that neither retailers nor villagers had knowledge about their effective application. In rural communities, rodenticides are available only at the larger stores (general dealers) and at monthly market stalls. At these stalls, some agrochemicals are sold illegally as rodenticides. Rodenticides are generally available in 100-g packages, and shop owners reported that they usually sell one packet per household. However, due to infrequent use, effective control cannot be achieved. A South African rodenticide manufacturer has agreed to modify and manufacture 'Kness' break-back traps (originally designed and manufactured by a US-based company), which were used successfully in Mozambique (R7372). These traps are sufficiently sensitive and cost-effective (based on the number of rodents caught per trap) when compared with alternatives such as rodenticides. The engagement of a local manufacturer ensures sustainability, and a pricing structure independent of the ZAR–US$ exchange rate.

Literacy in rural South Africa, especially among household heads, is low. It was therefore decided to use regional radio stations to promote effective rodent-control management. Two radio talks were broadcast on the importance of rodent control for health and food security.

The results of the project were discussed with stakeholders and major role-players such as the Department of Agriculture and the Pest Control Services Industries Board. An invitation by the latter to revise the current rodent-control curriculum demonstrates its willingness to improve present rodent-control training. Tswane University of Technology has requested assistance in revising its introductory rodent control course.

The project demonstrated that rodent-control strategies previously used in Mozambique (R7372) are effective in the peri-urban communities and different agro-ecological and geographic areas of Limpopo Province. Resistance to policy changes by some institutions will take time to overcome, but this project has marked a move forward in both understanding and improving rodent management.

## FURTHER APPLICATION

This work is being extended through project R8441. The outputs of this project could usefully be disseminated to poor rural and peri-urban communities in other parts of South Africa.

# Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: implementation phase

**R8228**

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September 2002–December 2005

See R6735, *Perspectives on Pests 1996–2000*, pp. 100–102

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KUMAR, S.P. *et al*. (2005) India to release the first fungal pathogen for the classical biological control of a weed. *Biological Control and Information* 26: 71N–72N.

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*Mikania micrantha* originates from the Neotropics, but has become an invasive, alien weed in many regions within the tropical moist forest zones of Asia, and is still invading new areas. The 'mile-a-minute' vine smothers vegetation in both agricultural and natural ecosystems. This project aimed to import into India, from Trinidad, a previously evaluated isolate of the rust fungus *Puccinia spegazzinii*. A release permit has now been issued by the Indian Ministry of Agriculture, for use of *P. spegazzinii* as a classical biocontrol agent. Under quarantine conditions in Delhi, final screening and assessment of the rust was completed prior to its release. The rust is now being established in the field in two regions of India: the Western Ghats (Kerala) and Assam. This is the first exotic fungal agent to be released in Asia for weed control.

## ISSUES

The 'mile-a-minute' weed, *Mikania micrantha*, is invading many regions throughout the moist forest zones of tropical Asia, where it is strangling forest species and crops. A native of tropical America, it was introduced to north-eastern India as a cover crop and allegedly as camouflage for airfields in the 1940s, but its impact has escalated in recent decades due to widespread cutting and degradation of natural forests. In Assam, *Mikania*, having colonised degraded forestland, then invades adjoining tea gardens and village vegetable plots. The weed was introduced to the Western Ghats, in Kerala, south-western India in the 1980s, and is still invading new areas in this region.

*A worker cutting* Mikania *weed in sugarcane (top); tea grown on terraces in the Western Ghats of Kerala (below: from www.tug.org.in)*

In Kerala, *Mikania* is widespread in home gardens, plantations and natural forests. Unchecked, *Mikania* severely affects agricultural production, and controlling it by hand-weeding increases the cost of cultivation for both commercial and smallholder

*Tropical American rust fungus,* Puccinia spegazzinii*, attacking Mikania weed*

farmers. Production costs for important crops, such as pineapple, plantain and oil palm, have escalated in affected regions. The weed also has a severe impact on teak and other forest plantation species. Smallholders have either abandoned cultivation of subsistence and tree crops in *Mikania*-infested areas, or changed to other crops. This weed also affects the livelihoods of tribal people living in forests of Kerala by impeding the collection of forest products.

A previous project (R6735) had identified a tropical American rust fungus, *Puccinia spegazzinii*, as suitable for use as a biological control agent for *Mikania*. Eleven samples of the rust from six countries (Argentina, Brazil, Costa Rica, Ecuador, Peru and Trinidad) were evaluated by CABI Bioscience in its quarantine glasshouse in the UK. A pathotype from Trinidad proved to be virulent against a wide range of *Mikania* genotypes present in India, including all the weed populations that were screened from the Western Ghats.

This strain of *P. spegazzinii* was then tested against 55 non-target species, including plants closely related to *Mikania* and crop plants. The rust proved to be totally specific to *Mikania*, against which it is highly damaging, resulting in leaf, petiole and stem cankers, and death of the whole plant. Although a suite of natural enemies may often be required to achieve significant control of invasive alien weeds, it appears that in the case of *Mikania*, *P. spegazzinii* may prove to be the 'silver bullet'. The aim of the current project was to implement a classical biocontrol strategy as an environmentally benign, sustainable, effective solution for reducing the impact of this noxious weed in India.

## ACHIEVEMENTS

As part of the earlier phase of this work, KFRI had quantified the sociological and economical impacts of the weed, together with its distribution in Kerala. Building on that work, KFRI developed a surveillance programme to cover the neighbouring states of Karnataka, Goa and Tamil Nadu. This showed that *Mikania* is dispersing steadily into Tamil Nadu, and has moved much closer to the border between Kerala and Karnataka.

Discussions with policy-makers led to the Government of India issuing a permit for import of the rust fungus *P. spegazzinii* for potential *Mikania* control. This is the first time that the Government of India has allowed importation of an exotic pathogen as a weed biocontrol agent – a first for India, and for continental Asia.

Additional host-specificity testing has been completed at NBPGR, New Delhi; only the target weed

*Checking on progress of the rust applied in the field*

*Mile-a-minute weed, described as a 'green tidal wave', pictured strangling Assam tea (top left), banana (left), and degraded forest in Assam (right)*

was found to be susceptible to the rust. These results were submitted to the Indian Quarantine Authorities, along with the application for a release permit for *P. spegazzinii*, in February 2005. In June 2005 the Plant Protection Adviser to the Government of India (Ministry of Agriculture) agreed to issue the permit for field release of the rust for *Mikania* control in Kerala and Assam.

The biological control agent will spread naturally and evidence suggests that, over time, it will not only arrest the progress of the weed, but will reduce the current level of weed infestation. This will assist plantations and subsistence farmers by reducing the inputs they have to make to control the weed, and will be of no cost to them. Most importantly, for tea in Assam, this should result in a reduction of chemical herbicides, the residues of which have been a cause for concern with EU tea importing countries.

Permanent weed sample plots have been established in Kerala by KFRI and in Assam by AAU. Assessments have been made of the density of *Mikania* weed in these plots prior to the release of the rust. A rust propagation unit has been constructed in Assam, at AAU, with guidance provided by CABI. The rust was prepared for shipment to India at CABI Bioscience, UK, in quarantine, and voucher specimens of the rust have been preserved in liquid nitrogen. The rust has been shipped to India and established in quarantine in New Delhi, and host-range testing has been completed.

As the rust can survive only on living plants, it is necessary to transport it into the field for release as an infection of pot-grown *Mikania* plants. Rust-infected plants, prepared at the NBPGR, were packed in cool boxes and hand-carried by air to Assam and Kerala. Some of these plants were planted directly in the field within dense stands of *Mikania*. The rest of the plants were taken to the propagation units at KFRI and AAU to bulk up the rust on a large number of potted plants. This will allow for an intensive, wide-ranging release programme to follow.

Workshops for scientists, extensionists and forestry workers will be held in Assam and Kerala. Studies to look at the establishment and impact of the rust have been initiated.

Educational materials are being produced, and a comprehensive farmer information and public awareness campaign is being implemented to support this innovative approach to weed control in Asia.

## FURTHER APPLICATION

The process used by the project team is being recorded under a short project: R8502, Promotion of weed biocontrol in Asia: the *Mikania micrantha* experience. A similar project, funded under the Defra Darwin Initiative, began in 2003 for China, where *Mikania* is also a serious weed. Lessons learnt from the DFID research have enabled the Chinese to fast-track the processes – the 10-year Indian experience has enabled the Chinese to introduce and release the rust within two years.

# Management of fruit flies in India

**R8089**

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*Collaborating institutions throughout India (see page 138)*

December 2001–March 2006

See R6924, R7447, *Perspectives on Pests 1996–2000*, p. 86

Tephritid fruit flies cause serious damage to fruit and vegetables in South Asia and throughout much of the world. Through a multidisciplinary survey, this project has established the economic, social and environmental costs of fruit flies, and constraints to their improved management. Food bait and sexual parapheromone lure controls have been tested, along with social studies of the resources, priorities and perceptions of farmers and village institutions. Practical management strategies that are effective and sustainable at farm and village level have been determined with collaborating Indian research, extension and fruit marketing agencies. Establishment of local fruit fly research centres, the South Asia Fruit Fly Network and its associated website, and a series of project workshops has generated a spirit of cooperation and cohesion within the fruit fly research community in India, and should help to provide a research base on which to build further locally funded projects.

## ISSUES

India is the world's largest tropical and subtropical fruit producer – and the largest mango producer, with 65% of global production. The mango export industry is a priority area, and locally tree fruits are valuable sources of nutrition and vitamins. Tephritid fruit flies (*Bactrocera* spp. and *Dacus* spp.) cause serious damage to both fruit and vegetables in South Asia and throughout much of the world. A number of host crops are of particular importance to the poor and vulnerable. The crops for which production statistics do not exist are, because of their small-scale nature and small commercial potential, of greatest significance for the poorest farmers. Guava is called 'poor man's fruit' because of its poor keeping qualities and inability to ripen after harvest, which make it unsuitable for harvesting green to ripen in transit to market, and is widely the preserve of small and local producers. Jujube is also called 'poor man's fruit' in northern Gujarat because of its tolerance of dry conditions, allowing it often to be the only productive plant that can be grown on what is often waste ground. Sapota is widely grown in Gujarat, and in Karnataka is sometimes valued by smallholders even more than mango because its production is high and its fruiting season long.

Fruit flies are probably the most serious cause of pest losses to many tree fruits and most cucurbits. Anecdotal evidence suggests that many subsistence growers of staple crops such as rice and cereals, who are in a potential position to move up to the cultivation of cucurbits for market, are prevented from doing so by pests, mainly fruit flies. Control of fruit flies, particularly by cheap methods that need no access to capital goods such as sprayers, should offer significant improvements in living standards.

While trap catches can indicate seasonal or annual fluctuations of a single species in time, they are

*Cooperatives are vital links between farmers and the lucrative urban marketplace*

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Bactrocera zonata *(left),* Dacus ciliatus *(right).*
*(photos: Ian M. White; © 1999 Natural History Museum, UK, reproduced with permission)*

a poor representation of actual infestation losses due to the extreme differential susceptibility of different species to different lures, with some being attracted to none. Catches often correlate poorly with infestation at field level. As a result, the relative role of various species in causing economic damage is less well understood than their geographical distribution.

## ACHIEVEMENTS

Through a key informant survey, this project has determined the extent of damage caused by fruit flies to fruits and vegetables in India (see table), and the difficulties experienced, particularly by smallholder growers, in controlling them successfully on individual plots.

Building on previous work in Pakistan (R6924, R7447), the fruit fly species affecting orchard fruit such as mangoes could be attracted to the parapheromone lure methyl-eugenol, which is available from specialist suppliers as a food additive. Wooden blocks soaked in lure plus insecticide obtained good control of flies in mangoes. The type of traps previously used in India, either of soaked cotton wool, water or using extracts from *Ocimum* (holy basil), were found to obtain levels of kill substantially inferior to lure blocks, which also have the key advantage of being easy to use, and do not require weekly replacement. Lures may not provide full control in all cases, however – when farms are small and pressure intense, infestation is still substantial and other controls need to be held in reserve.

*Bitter gourd fruit protected from fruit flies by cooperative control being loaded onto a lorry for the market in Thrissur, Kerala (photo: J. Thomas)*

The species of fruit flies affecting cucurbit vegetables (mainly *Bactrocera cucurbitae*) are attracted to cuelure, a commercially available parapheromone. Cuelure is much more expensive than methyleugenol and is available only in weak preparations, so for small-scale farmers these flies are most economically controlled by liquid baits mixed with insecticide, which attract a wide range of flies but require more frequent replacement than wooden lure blocks.

Studies concluded that the attraction of the same species of fly in different parts of the country to different baits was not consistent. Southern flies tended to favour banana baits to jaggery (unrefined sugar) baits, whereas north-western flies tended to favour jaggery, with eastern and central flies in an indeterminate position. Locally produced baits had different effects in different parts of the country, probably reflecting the

| Estimates of production and losses to fruit flies of orchard fruits and cucurbit vegetables in India | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calculated production and economic loss* | | | | | | Loss attributable to main fruit fly species† | | | | | |
| | (lakh‡ tonnes) | | | (million £) | | | (lakh tonnes) | | | (million £) | | |
| | U | P | Total | U | P | Total | Bd | Bz | Bcr | Bd | Bz | Bcr |
| Mango | 6.72 | 1.28 | 8 | 0.84 | 0.16 | 1 | 4.24 | 2.95 | 0.81 | 0.53 | 0.37 | 0.1 |
| Guava | 4.69 | 0 | 4.69 | 0.35 | 0 | 0.35 | 1.9 | 2.61 | 0.17 | 0.14 | 0.2 | 0.01 |
| Jujube | 0.12 | 0 | 0.13 | 0.01 | 0 | 0.01 | 0.06 | 0.06 | 0 | 0 | 0 | 0 |
| Sapota | 0.13 | 0 | 0.13 | 0.01 | 0 | 0.01 | 0.06 | 0.07 | 0.01 | 0.01 | 0.01 | 0 |
| Phalsa | 0.08 | 0 | 0.08 | 0.01 | 0 | 0.01 | 0.04 | 0.04 | 0 | 0 | 0 | 0 |
| Peach | 0.04 | 0 | 0.04 | 0 | 0 | 0 | 0.01 | 0.03 | 0 | 0 | 0 | 0 |
| Apricot | 0.04 | 0 | 0.04 | 0 | 0 | 0 | 1.18 | 2.4 | 0.02 | 0 | 0 | 0 |
| Total | 11.82 | 1.29 | 13.11 | 1.23 | 0.16 | 1.39 | 7.48 | 8.16 | 1.02 | 0.69 | 0.58 | 0.12 |
| | | | | | | | Bcu | Bt | Dc | Bcu | Bt | Dc |
| Cucumber | 2.45 | 1.11 | 3.56 | 0.61 | 0.28 | 0.89 | 3.28 | 0 | 0.28 | 0.82 | 0 | 0.07 |
| Muskmelon | 2.71 | 1.25 | 3.96 | 0.2 | 0.09 | 0.3 | 3.57 | 0 | 0.39 | 0.27 | 0 | 0.03 |
| Watermelon | 0.71 | 0.4 | 1.11 | 0.03 | 0.02 | 0.05 | 0.99 | 0.01 | 0.11 | 0.04 | 0 | 0 |
| Cooking melon | 0.26 | 0.16 | 0.41 | 0.02 | 0.01 | 0.03 | 0.37 | 0 | 0.04 | 0.02 | 0 | 0 |
| Pumpkin | 1.4 | 0.33 | 1.73 | 0.06 | 0.01 | 0.08 | 1.32 | | 0.09 | 0.06 | 0.01 | 0 |
| Bitter gourd | 1.43 | 0.62 | 2.05 | 0.27 | 0.12 | 0.38 | 1.85 | 0.05 | 0.16 | 0.35 | 0.01 | 0.03 |
| Small gourd | 0.48 | 0.21 | 0.69 | 0.09 | 0.04 | 0.13 | 0.6 | 0.05 | 0.04 | 0.11 | 0.01 | 0.01 |
| Ridge gourd | 0.33 | 0.11 | 0.44 | 0.02 | 0.01 | 0.03 | 0.38 | 0.04 | 0.02 | 0.02 | 0 | 0 |
| Bottle gourd | 0.55 | 0.16 | 0.7 | 0.03 | 0.01 | 0.04 | 0.65 | 0.01 | 0.05 | 0.04 | 0 | 0 |
| Snake gourd | 0.78 | 0.28 | 1.06 | 0.07 | 0.03 | 0.1 | 0.96 | 0.04 | 0.06 | 0.09 | 0 | 0.01 |
| Sponge gourd | 0.41 | 0.12 | 0.53 | 0.03 | 0.01 | 0.03 | 0.49 | 0.02 | 0.03 | 0.03 | 0 | 0 |
| Chayot | 0.26 | 0.11 | 0.38 | 0.02 | 0.01 | 0.02 | 0.31 | 0.04 | 0.03 | 0.02 | 0 | 0 |
| Ash gourd | 1.29 | 0.42 | 1.71 | 0.08 | 0.03 | 0.11 | 1.48 | 0.12 | 0.1 | 0.09 | 0.01 | 0.01 |
| Sweet gourd | 0.21 | 0.06 | 0.28 | 0.03 | 0.01 | 0.03 | 0.21 | 0.07 | 0 | 0.03 | 0.01 | 0 |
| Total | 13.26 | 5.34 | 18.61 | 1.56 | 0.66 | 2.22 | 16.44 | 0.78 | 1.39 | 1.99 | 0.06 | 0.17 |

*U, unprotected; P, protected.
†Fruit fly pests of orchard crops: Bd, *Bactrocera dorsalis*, Bz, *Bactrocera zonata*, Bcr, *Bactrocera correcta*; fruit fly pests of cucurbit vegetables: Bcu, *Bactrocera cucurbitae*; Bt, *Bactrocera tau*; Dc, *Dacus ciliatus*.
‡1 lakh = 100,000.

great diversity of fruit fly complexes within India.

Weekly applications of baits can obtain as good control as cover sprays, and their ease of application allows them to be carried out more frequently. Comparative trials on farmers' fields throughout India, in a wide variety of crops and conditions, consistently found that home-made baits of banana or jaggery obtained protection as good as or, more often better than, expensive and environmentally damaging cover sprays of insecticides, and were of great interest to farmers.

Bait application and lure blocks do not provide complete protection, and many farmers may find they can be profitably used together – when used in combination the two methods did not interfere with each other, and their effects in combination were multiplicative.

Both bait application and lure blocks benefited substantially from being used over areas of a whole village rather than on a single farm, and village-level cooperative control offers great advantages. Cooperative control is most easily introduced where cooperatives already exist, or there are similar bodies around which groups of farmers organise and that can provide a channel for the distribution of lures and advice on how to use them. Surveys of growers and local organisations have established constraints and opportunities for village-level cooperative control efforts to be organised.

Bait plus insecticide application on individual trees provides partial control of fruit flies attacking fruit, but is of less benefit for vegetable fruit flies. It is unlikely that individual tree or small-plot control using cover sprays or bait

*Assessing control of flies with home-made coconut traps containing mashed banana and insecticide – behind the coconut trap is a bottle trap used to monitor fly populations (photo: T. Jiji)*

applications would provide reliable quantities of market-quality fruit for smallholders, especially for highly susceptible fruits such as guava, or for cucurbits.

Male annihilation was shown to provide significant, but not complete, control on plots as small as 0.2 ha.

During 2004 and 2005 several large-area male annihilation control trials were carried out, ranging from 1 to 10 $km^2$, to establish the limits on economies/ecology of scale. The 1-$km^2$ trial in 2004 showed incursions into the controlled grid of approximately 100–150 m. However, 'fingers' of incursions spread into the control area on occasions for 300–400 m. This suggests that village-level control using this technique (which is insecticide-free) must be economically viable, including at least a 100-m buffer zone outside the area that needs control, and that the risk level would be decreased further by extending the buffer to 300 m. Trials on a larger scale in 2005 will help to determine the ecological features of incursions so that this advice can be defined more accurately. The benefit to be gained within a control zone will be determined by the number and type of fruit trees, and a simple calculator to show whether a particular zone would benefit from cooperative area-wide treatment will be developed using data from the 2005 season.

Collaboration with a fresh fruit and vegetable retailer has established quality and availability issues that must be addressed within the food-supply chain to generate additional income for smallholder fruit and vegetable growers if they apply improved fruit fly management on a village-level scale. Work with Mother Dairy (a large cooperative organisation of the National Dairy Development Board) has been examining how cooperative fruit fly control at village level can be connected with other quality and value-adding processes (such as grading and packing of produce locally) to increase small-farm incomes and improve their position in the food supply chain.

*Above, healthy gourd and below, infested with fruit fly maggots (photo: T. Jiji)*

The project has supported the establishment of a cooperative international association of fruit fly scientists and practitioners, the South Asia Fruit Fly Network (SAFFN), hosted at Gujarat Agricultural University. SAFFN is based on an open-access website (www.southasiafruitfly.net) and produces a regular newsletter on developments in fruit fly management.

The project has established fruit fly research centres with principal investigators and junior researchers at the following institutions, with overall coordination from the Indian Agricultural Research Institute, New Delhi:

- Gujarat Agricultural University (GAU) – three campuses at Anand, Ghandevi and Palanpur
- Kerala Agricultural University (KAU) – two campuses at Thrissur and Thrivananthapuram
- Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh
- Central Institute for Subtropical Horticulture (CISH), Lucknow, Uttar Pradesh
- Indian Institute of Horticultural Research (IIHR), Bhubaneshwar, Orissa.

## FURTHER APPLICATION

An extension of the project through the 2005 growing season (R8440) allowed further work on optimising the cost–benefit return from lures at different densities. The effectiveness of home-made bait sprays was confirmed in two small communities of farmers in Kerala and Goa, where water access precluded the use of cover sprays. In collaboration with the vigorous local Cooperative Amalsad in southern Gujarat, increased returns were demonstrated when cooperative wide-area control was extended from 1 to 10 $km^2$.

SAFFN is now running, and during the project extension period further assistance will be given to help this become an active focus for research and management exchanges. A final workshop, held in Goa in October 2005, brought together the research results, and inputs from farmers and cooperatives, to produce a final set of recommendations for economically optimal integrated fruit fly management at both farm and community levels.

# Promotion and impact assessment of tomatoes resistant to tomato leaf curl virus disease

**R8247**

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January 2003–March 2005

See R6627, *Perspectives on Pests 1996–2000*, pp. 88–90

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RAJESHWARI, R., CHOWDA REDDY, R.V., MARUTHI, M.N., COLVIN, J., SEAL, S.E. and MUNIYAPPA, V. (2005) Host range, vector relationships and sequence comparison of a begomovirus infecting hibiscus in India. *Annals of Applied Biology* 147: 15–25.

Whitefly (*Bemisia tabaci*) and tomato leaf curl virus disease (ToLCVD) currently cause huge economic losses in most tropical and subtropical regions of the world. Building on previous strategic work in India that developed three open-pollinated (true-breeding) ToLCVD-resistant tomato varieties, this applied project aimed to create a significant developmental impact by creating new mechanisms and partnerships for the sustainable delivery of research products to farmers. The team did this by first obtaining official authorisation to release these new resistant varieties, and then promoting and disseminating them through novel funding mechanisms or licence agreements. The three ToLCVD-resistant varieties were released successfully and notified in the *Gazette of India* for use throughout the country. Negotiations with commercial vegetable seed producers led to 16 taking up the rights, on a non-exclusive basis, to multiply and distribute the varieties and/or to use them as parental material to develop ToLCVD-resistant hybrids. Data have been collected and published on the performance of the varieties in different Indian states, and on the different ToLCV species and *B. tabaci* populations present in those locations. Impact assessment data showed that farmers could obtain up to 10 times the profits they used to achieve growing ToLCVD-susceptible open-pollinated varieties, and that they used the extra income to improve nutrition, children's education and health. To ensure sustainability, a revolving fund has been set up by the National Seed Project of UASB, where receipts from seed sales through various outlets are used to produce replacement seed that, in turn, will be sold.

## ISSUES

After China, India is the world's second largest vegetable producer, with 5.5 million hectares of land under vegetable crops. Production in India is limited by losses caused by insect pests and diseases to the extent that the *per capita* consumption of vegetables is only 25–33% of the daily minimum requirement. Over the previous two decades, whiteflies have been gaining worldwide prominence as important crop pests, causing direct and indirect losses through phloem feeding, excretion of honeydew and transmission of viruses. As part of a response to the problem in tomatoes, the UASB screened 1306 *Lycopersicon* genotypes for resistance to ToLCV, with the long-term objective of introducing ToLCV-resistance genes into edible

*Vybhav (left) and a ToLCV-resistant hybrid developed from it (right) by the commercial company Namdhari Seeds*

*The tomato crop was severely infected with ToLCV in the 1999 epidemic season at Kaparasiddanahalli, Kolar taluk – this farmer is ploughing in the tomato crop without harvesting a single fruit*

tomatoes through conventional plant-breeding techniques. AVRDC provided the project with tomato germplasm that could be screened to identify the best sources of resistance to ToLCVD in southern India.

Earlier farmer-participatory trials (R6627) identified the ToLCVD-resistant varieties TLB111, TLB130 and TLB182. The poorer farmers usually grow open-pollinated tomato varieties as they can keep their own seed, although they recognise that yields are lower than the relatively expensive hybrid varieties. In the past, the varieties available to them have had no ToLCV resistance, so tomato production involved particularly high financial risks in the ToLCV-epidemic season, often resulting in complete crop failure and loss of capital invested in the crop. The new varieties have the following benefits.

- Greater than 100% increase in yields compared with susceptible varieties in the presence of ToCLV disease, and on-farm trial benefit-to-cost ratios as high as 6.6 to 1.
- A 50–75% reduction in use of insecticides for control of whiteflies and geminiviruses, with consequent assumed environmental and consumer health benefits.
- Increased tomato production during ToLCVD-epidemic periods, leading to reduced seasonality of tomato supply and lower prices for consumers.
- Lower production costs and higher productivity, leading to higher income for farmers and other stakeholders involved in the supply chain.
- Reduced risk of crop losses from ToLCVD may encourage more poor farmers to grow tomatoes.
- Improved understanding of disease epidemiology, which has already led to the design of rational and environmentally friendly management techniques.
- Increased understanding and improved awareness of whiteflies and ToLCV among stakeholders and the general public.
- Facilitation of ToLCV-resistant hybrid development by the private sector.

These varieties have the potential to reach millions of tomato producers in India, including the poorer farmers, and to have a major impact. The current project aimed to fulfil that potential through making ToLCV-resistant hybrids available to farmers through both the public- and private-sector routes.

## ACHIEVEMENTS

This project carried forward earlier assessment of whitefly and ToLCV diversity, identification of sources of resistance, and productive collaboration with AVRDC and Indian national agricultural research systems to develop productive, farmer-preferred, disease-resistant tomato varieties.

Three tomato varieties, Sankranthi, Nandi and Vybhav, have been released and assigned national identity numbers (IC 296388, IC 296389, IC 296390). Official notification of variety names was published in the *Gazette of India*, signifying that they can be used throughout India.

The UASB Technology Transfer Committee carried out negotiations with 10 vegetable seed companies, all of which have purchased breeder-quality seed from UASB. The varieties were grown by the companies in several additional states, including Himachal Pradesh (northern India) and Nagpur (central India), as part of their rigorous multi-locational trial procedure. Nine of the companies stated that the tomatoes did not show any ToLCVD symptoms. From molecular analysis of samples of ToLCV-infected tomato plants, weeds and *Bemisia tabaci* populations, the non-indigenous B biotype of *B. tabaci* was identified in Kolar and Nagamangala in Karnataka, and several locations in Gujarat. This supports previous predictions that its distribution within India would expand.

Analysis of the coat protein DNA sequence data for the viruses found in plants with leaf curl symptoms showed that there are five different ToLCV groups in India. ToLCVs were detected in alternative hosts including chilli, cowpea, okra and tobacco, as well as the weeds *Croton* sp., *Parthenium* sp. and *Malvastrum* sp. Papaya leaf curl virus and pepper leaf curl Bangladesh virus were also detected in tomato for the first time. At least two completely new ToLCV species were identified. Colonies of three *B. tabaci* populations from eggplant, collected from Rannibenur, Coimbatore and Belgaum, and a population from the weed *Euphorbia geniculata*, collected from Bangalore, were established. The CO1 gene sequences of the Rannibenur, Coimbatore and Bangalore populations were obtained and fitted into previously identified population clusters. The reciprocal crosses were carried out.

Regions were identified in Karnataka and Andhra Pradesh where open-pollinated tomato varieties are widely grown. More than 90 farmers were visited and socio-economic data collected from them. As an additional activity, a small group of 20 farmers was given the ToLCV-resistant tomato seed. These seeds were monitored closely and compared with another group in the same area, growing the traditional ToLCV-susceptible varieties. A comparison of the benefits/costs showed that those growing the project's tomatoes made up to 10 times more profit than those growing ToLCV-susceptible open-pollinated varieties.

Links were also maintained with the private seed companies that purchased the project's ToLCV-resistant lines, in order to collect impact data. Companies such as Namdhari, Cee Kay and Ankur Seeds are making rapid progress towards producing ToLCV-resistant hybrid varieties with a project variety as one of the parents.

A policy briefing paper, 'Countering the whitefly and plant-virus disease threat to sustainable livelihoods in India', will be handed out to the appropriate participants at the project workshop, which is to be held during the extension period in 2005. Project staff provided information on best cultivation practices and prepared a single-sheet pamphlet, written in Kannada, the local language


*Open-pollinated tomato fruits at market at Kappalamadugu, Mulbagil taluk, Kolar District, Karnataka*

*Krishimela, an annual agricultural fair attended by 25,000–30,000 farmers from southern districts of Karnataka, is organised by the UASB to exhibit technologies developed by the university to farmers: here men and women farmers view a check-plot of ToLCV-susceptible tomato showing severe disease symptoms*

of Karnataka. This described the resistant tomato varieties' characteristics, their high yield potential, low production costs, and the significant advantage that they can be grown without insecticides, which are normally sprayed intensively on susceptible tomato varieties to protect them from *B. tabaci* and ToLCVD. Press articles and radio and TV programmes have been released on the project's outputs, and a project website (www.tomatoleafcurland whitefly.org) has been established by UASB to disseminate the results, achievements and lessons learned.

The involvement of the private sector in producing ToLCV-resistant hybrids is likely to create enormous impact among better-off tomato growers, which will in turn benefit poorer urban consumers who need cheap sources of nutritious vegetables. To ensure that the poorest growers will be able to access resistant open-pollinated varieties, a revolving fund has been set up by the National Seed Project of UASB. Fifty thousand seed pouches have been produced for the sale of ToLCV-resistant tomato varieties, and the UASB has conducted two field days and two training programmes at Mandya and Nagamangala taluks. Due to these promotional efforts, the total quantity of seeds sold so far is around 6 kg, and demand is increasing.

## FURTHER APPLICATION

The project has the potential to generate enormous impact throughout India, as well as in Africa, the Caribbean and Asia. Links made with 10 private seed companies in India to develop ToLCV-resistant hybrids should have a significant impact in two to three years' time, even if only 30–50% of these companies succeed. Working with 10 companies rather than one will create competition in the marketplace and stimulate farmer demand for quality seed – good for the seed industry as a whole, and for producers and consumers as it should result in lower seed and product prices. Sixty per cent of the area under tomato production in India involves open-pollinated varieties grown by the poorest farmers – responding to this demand has provided more scope for wider and facilitated dissemination to more farmers.

In order to maximise impact, a nine-month extension phase (R8425) took place in 2005 with activities aimed at promoting the uptake and sustainable adoption of the technologies and ToLCV-management practices with poorer growers. If successful, this will ensure that tomatoes can be grown successfully, even in the peak of the ToLCV-epidemic season, with greatly reduced insecticide use and associated benefits for farmers, consumers and the environment.

# Aflatoxin contamination of groundnut in southern India

**R8298**

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Groundnut is a key commodity in the livelihoods of the rural poor in semi-arid Andhra Pradesh, as source of food for humans and livestock, and as a source of income. Aflatoxin contamination in groundnut, resulting from fungal infection, has deleterious effects on both human and animal health – households relying on groundnut as a major source of protein face potentially severe health risks. Fourteen high-yielding, aflatoxin-resistant groundnut cultivars were evaluated in farmer participatory varietal selection trials. Varietal performance and farmer preferences varied with district. Cultivars selected by farmers for further on-farm testing produced higher pod and haulm yields than local controls. Two varieties, ICGV 93328 and ICGVs 94434, produced 20–40% higher pod yield in 12 of 15 farmers' fields; three varieties (ICGVs 91284, 93328, 94434) had notably low aflatoxin contamination. Seed from large, mature pods in most cultivars had negligible levels of aflatoxin, whereas high levels were found in insect-damaged pods. Mechanical threshers were introduced for early pod stripping to avoid stacking the groundnut harvest, which enhances aflatoxin contamination. Threshers were modified to sort pods based on quality. In addition, a low-cost method for reducing aflatoxin contamination in groundnut, based on the application of compost, *Trichoderma*, gypsum, cereal residue and their combination, was tested on-station with largely positive results.

## ISSUES

Aflatoxins are highly toxic and carcinogenic chemical substances, produced by the fungi *Aspergillus flavus* and *A. parasiticus* on a variety of agricultural commodities including groundnut. The economic implications of aflatoxin, and its potential health threat to humans as well as livestock, have created a clear need to eliminate or reduce aflatoxin contamination in human food and animal feed.

Infection of groundnut by *A. flavus* occurs under both pre- and post-harvest and storage conditions. The growth of *A. flavus* and consequent aflatoxin production depends on a number factors, including temperature, humidity and kernel moisture content. Crops growing in semi-arid climates, where there is the likelihood of drought, are particularly at risk of pre-harvest contamination. High seed moisture content during storage also increases the risk of contamination. Several management options are available to reduce aflatoxin contamination in groundnut, including cultural practices, genetic resistance, biological control and integrated management.

*Conidial heads of* Aspergillus flavus

Aflatoxin contamination is widespread throughout the groundnut-based food and feed chains. Awareness of aflatoxins and the associated economic and health risks, and of technologies to reduce the risk of aflatoxin contamination, was found to be lacking among farmers, traders and other stakeholders. This project was undertaken to evaluate and implement low-cost aflatoxin-reducing technologies at production and processing levels, and to promote awareness about aflatoxins among the farming community, NGOs in agriculture,

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WALIYAR, F., REDDY, S.V., SUBRAMANYAM, K. *et al.* (2003). Importance of mycotoxins in food and feed in India. *Aspects of Applied Biology* 68:147–154.

website: www.aflatoxin.info

policy-makers and consumers. This project built on previous work (R7809 on reducing groundnut aflatoxin levels and R7346 on Plant diseases and crop residues in the Deccan Plateau).

## ACHIEVEMENTS

Fourteen high-yielding aflatoxin-resistant groundnut cultivars were evaluated in farmer participatory varietal section trials in Ananthapur and Chittoor districts of Andhra Pradesh. Fourteen lines were tested, and these produced 12–45% higher pod and haulm yields than local controls. However, as performance of these varieties varied in Chittoor and Anantapur districts, there was a need to implement farmer selection of lines. Based on their performance, farmers selected for cultivation seven cultivars in Chittoor (ICGVs 91279, 91284, 91324, 92302, 93305, 93328, 94434) and six cultivars in Anantapur (ICGVs 91278, 91315, 91328, 93305, 93379, 94434).

In the 2004 rainy season, the performance of these varieties was better in Chittoor than in Anantapur. Two varieties (ICGVs 93328 and ICGV 94434) produced 20–40% higher pod yield in 12 of 15 farmer fields in the Piler area of Chittoor District. Aflatoxin contamination was low in all cultivars tested at all locations during the 2003 rainy season. In 2004, three varieties (ICGVs 91284, 93328 and 94434) showed low aflatoxin contamination.

Seed from sound, mature pods in most of the cultivars had negligible levels of aflatoxin, whereas high levels were found in insect-damaged pods.

Milk production and milk aflatoxin content in dairy animals fed a diet based either on improved groundnut cultivars ICGV 91114 or on local cultivar TMV2 were investigated in three villages in Anantapur:

- milk production on ICGV 91114 was about 400 ml/day/animal) higher than on TMV2
- aflatoxin content in improved and local groundnut haulms was far below the Indian threshold level for fodder, and only groundnut cake was about threefold above the Indian threshold level
- close to 50% of the milk samples collected during feeding trials had non-permissible levels of aflatoxins.

Flyers depicting the risks due to aflatoxins and various technologies to minimise them were produced in English, Telugu, Hindi and French, and disseminated to various stakeholders.

Mechanical threshers were introduced for early pod stripping and to avoid stacking the groundnut harvest. This intervention has provided a new perspective on the use of mechanical threshers as an aflatoxin-management tool. Threshers were successfully modified to sort pods based on quality. Efforts were initiated to obtain government subsidies for the purchase of mechanical threshers.

A panel was formed, including representatives of farmers, scientists, NGOs in agriculture and consumer markets, health officials and government policy-makers. This panel outlined an action plan to address the aflatoxin problem at various levels, mainly to evolve a ‘sensitive communication strategy for increasing awareness about mycotoxins’. Andhra Pradesh State Department of Agriculture agreed to consider subsidies for purchasing threshers and sprinklers in the villages that took part in participatory varietal section. Medical professionals offered to work out plans to inform medical staff and nutritionists about health-related risks due to aflatoxins.

Participatory processes, both pre- and post-harvest, have been successfully piloted with NGOs and farmers. Pre-harvest processes can be scaled up successfully as long as seed is available and this does not demand too much quantitative evaluation. NGOs, self-help groups and farmers are enthusiastic about the process and about the potential outputs.

A low-cost method for reducing aflatoxin contamination in groundnut was developed. This is based on soil amendment with compost, *Trichoderma*, gypsum, cereal residues and their combination, using two cultivars. The highest reduction in aflatoxin contamination (91%) was observed with gypsum + *Trichoderma* application in variety JL 24. Application with cereal residue or gypsum showed 12–40% reduction in aflatoxin level in JL 24. In variety J 11, gypsum + *Trichoderma* + compost application showed a 99% reduction in aflatoxin, and five other treatment combinations also showed varying levels of reduction.

Participatory processes with new cultivars have created awareness and a demand for improved cultivars and seeds among farmers and NGOs representing them. Seed systems need to be stabilised to ensure a supply of good-quality seed at an affordable price. Links have been established, for example with exporting organisations. Awareness has been raised among state policy-makers, agriculture and extension departments, NGOs, veterinary organisations, the medical profession and processors, and the new panel provides a mechanism to maintain and build on these links.

## FURTHER APPLICATION

The participatory varietal section programme provides an excellent means to interact with all stakeholders in the groundnut-based system. New cultivars are of great interest to farmers and help to enthuse farmers (and NGOs) about the whole process. As 2003 was the first year of this activity, seed multiplication will take time, especially in drought-prone areas. Improved packages for application of various soil amendments will be evaluated on-farm with farmers and state extension networks for adoption.

# Effects of plant diseases on crop residues used for peri-urban dairy production on the Deccan Plateau

**R8339**

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October 2003–March 2005

Increased milk production in India will require improved yields of higher-quality crop residues for animal fodder. In Andhra Pradesh State, on the Deccan Plateau, groundnut crop residues are the main source of dry fodder for dairy animals. However, the nutritive value of crop residues is often low, and both sorghum and groundnut are susceptible to a number of diseases that reduce production and quality. Additionally, the development of mycotoxins by fungi on the residues is a serious threat to animal health and, through milk, to human health. In an attempt to tackle these constraints, disease-resistant, dual-purpose cultivars have been distributed to farmers, and village-level seed multiplication/distribution systems following integrated management of foliar diseases have been successfully developed. Farmers identified groundnut cultivar ICGV 91114 as outstanding for both grain and haulm production and quality. Farm surveys confirmed the higher yields of the new cultivar, and laboratory analyses and on-farm feeding trials showed improved nutritive value and milk production. The use of ICGV 91114 as part of an integrated disease management strategy will lead to improved food security and increased incomes. To achieve this, farmers must have assured access to good-quality seed. Unlike sorghum, for which the private seed industry can serve as a multiplier of improved cultivars, community-based seed-production systems for groundnut, will need to be established through farmer self-help groups and NGOs in order to achieve widespread seed dissemination.

## ISSUES

India has the largest population of ruminants in South Asia, and livestock production is an integral part of mixed farming systems. One of the most important technical constraints to animal production is the inadequate supply of high-quality feed resources throughout the year. As the area of common property resources for grazing continues to decline with increased cultivation and encroachment, dependence on crop residues will increase in importance.

On the Deccan Plateau in Andhra Pradesh, dual-purpose groundnuts are the major source of both pod and crop residues for ruminants. Yields are reduced by fungal diseases (late leaf spot and rust in groundnut; anthracnose and maize stripe virus in sorghum, which is also used as fodder). A further concern is the production of mycotoxins on crop residues by saprophytic fungi (*Aspergillus*, *Fusarium* and *Penicillium* spp.), which present a serious threat to the health of animals and, through contaminated milk, to human health (see R8298, page 143). A previous project (R7346) demonstrated that the integrated use of resistant genotypes and fungicides improved stover/haulm yields and nutritive value in both crops by more than 70%. This project aimed to disseminate a pro-poor integrated disease management strategy, based on superior, resistant, dual-purpose groundnut cultivars, to farmers in the major production area of Anantapur District.

## ACHIEVEMENTS

Some 214 farmers from 12 villages in Anantapur participated in rainy-season and post-rainy-season multiplication and distribution of seed of disease-resistant, dual-purpose groundnut cultivars, following integrated management of foliar diseases. Farmer participatory seed multiplication and distribution were undertaken with self-help groups, including women's groups.

Farmers have contributed to village seed banks by returning twice the quantity given to them for planting. Farmers identified the new disease-resistant, dual-purpose ICGV 91114 as the outstanding cultivar for both

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*High haulm and pod yields of disease-resistant, dual-purpose groundnut*

grain and haulm production and quality. The area under the new cultivars is now some 3000 hectares.

In June 2004, 150 farmers from five villages attended an orientation programme in the local language (Telugu) on the importance of farmer-participatory disease management of dual-purpose groundnuts. Discussions took place on foliar diseases, soilborne diseases, mycotoxin contamination and their management. In January 2005, 140 farmers and staff from national agricultural research systems, NGOs, ICRISAT and ILRI attended a stakeholder workshop on integrated crop/disease management in groundnut. The two meetings attracted considerable interest from the local media, and a number of newspaper reports were published in Telugu.

Surveys of farmers in the project villages indicated that groundnut accounts for 61–77% of the cropped area. Groundnut haulms provide >50% of dry fodder, and >25% of haulm fed to animals is traded within the village. Farmers also purchase substantial amounts of rice straw from 100–150 km away, and small quantities of sorghum straw from nearby villages. Compared with traditional varieties, ICGV 91114 is more resistant to diseases and drought. Mean pod yields for ICGV 91114 are 15% higher than those of local varieties, and mean haulm yields 17% higher. Farmers rated the palatability of the haulm of ICGV 91114, when fed to animals, as superior to that of local varieties. Laboratory analyses of on-farm groundnut haulms confirm that the nutritive value of improved cultivars is high. The ranges for crude protein content, *in vitro* digestibility and metabolisable energy level are 13.9–15.8, 63.2–65.3 and 8.8–9.2 MJ/kg, respectively.

Farmers perceived that foliar diseases reduce pod yields of traditional varieties by 10–20% and haulm production by 20–30%. Farmers observed disease incidence annually, but pest incidence was observed once in two years. The aflatoxin content of 72 groundnut haulm samples from six varieties (ICGS 44, ICGS 11, DRG 12, ICGV 86325, ICGV 92020 and ICGV 92093), from the CPP project on aflatoxins in groundnut (R7809), were analysed by enzyme-linked immunosorbent assay (ELISA). Results indicated that contamination in these samples was in the range 0–33 µg/kg, and about 25% of samples had higher than the permissible level. Among the six cultivars, all 15 haulm samples from ICGV 86325 were contaminated in the range 12–33 µg/kg. In the other cultivars, the level of aflatoxin contamination was very low.

Laboratory measurements of nutritive value were related to animal performance data using simple and multiple regression analyses. Laboratory techniques that predict animal performance were used for the development of near-infrared spectroscopy equations to provide a rapid, non-destructive analytical tool for estimating crop residue feeding value.

In 2003 the groundnut crop on farms was badly affected by drought. In 2004 rainfall was good, and data were available from farmers' crops for economic analysis. Seed is the most expensive input, accounting for 36–42% of total costs. Currently farmers receive about Rs24–28 per kg for seed of ICGV 91114, compared with Rs18–22 per kg for seed of traditional varieties (Rs80 ≈ £1). Per unit production, costs were lower for ICGV 91114 under both irrigated and rainfed conditions. Net returns to farmers were 25–29% higher as a result of growing the improved cultivar. Milk yields per animal on farm were 4.36 kg/day when fed improved cultivars and 3.92 kg/day with local varieties, an advantage of 0.44 kg per animal per day. Some 70–80% of milk is sold through both formal and informal channels, and income from sales ranges from 15–25% of household income.

Demand for seed of ICGV 91114 has exceeded supply. To meet requirements, several farmers with irrigation facilities have begun seed multiplication under guidance from NGOs and project scientists. Concurrently, seed traders have begun multiplying seed of the new cultivar on farmers' fields on a buy-back basis, in anticipation of high demand. The area under improved cultivars is now about 3000 hectares.

## FURTHER APPLICATION

As a result of an extension to the project (R8450), it is anticipated that some 18,570 hectares will be under new cultivars by 2006. At current rates of adoption, some 80,000 hectares of groundnut (10% of the total area) will be planted to improved cultivars in Andhra Pradesh by 2010. This would be still higher with further extension of the groundnut-growing area into the neighbouring states of Karnataka and Tamil Nadu.

# Characterisation of pigeonpea sterility mosaic virus to attain sustainable production in India

**R7452**

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September 1999–August 2002

The Indian subcontinent is the world's most important pigeonpea-growing region, with 82% of global cultivation in India. Pigeonpea is used in multipurpose ways and plays an important role, providing food security, balanced diet and source of income for millions of poor farmers living in marginal farming systems. Pigeonpea sterility mosaic virus disease, endemic on the subcontinent, can cause >90% yield reduction and is a major constraint on the crop yield and economic wellbeing of poor farmers. Cultivation of broad-based, durable, resistant cultivars is essential to mitigate losses to benefit these smallholders. This work has made a breakthrough in characterising pigeonpea sterility mosaic virus (PPSMV) and developing versatile and sensitive diagnostic tools for its detection, in order to supply broad-based disease-resistant genotypes to breeding programmes and to farmers for cultivation.

## ISSUES

Pigeonpea seed is the major dietary protein source for an estimated 1.1 billion people on the Indian subcontinent. This multipurpose crop plays an important role in food security and providing a balanced diet, and is important in allowing poor farmers and consumers access to both employment and food. Pigeonpea sterility mosaic virus disease (PPSMVD), the 'green plague of pigeonpea', is endemic on the subcontinent and is a major biotic constraint to pigeonpea production and the economic wellbeing of poor farmers. Annual losses estimated in 1993 have been valued at US$282 million in India and Nepal alone. The disease (first described in 1931) affects flower production, rendering the plant sterile.

*Pigeonpea sterility mosaic virus is transmitted by the eriophyid mite* Aceria cajani *(bar = 10 μm)*

Although cultivation of broad-based PPSMVD-resistant varieties had been identified as the most feasible and eco-friendly way to manage the disease, information was needed on its causal agent and aetiology.

## ACHIEVEMENTS

This project has unravelled the identity of the causal agent of PPSMVD, a seven-decade-old mystery. The isolation and characterisation of PPSMV revealed that it is a novel virus with an unusual combination of properties. This information is a significant scientific contribution to the field of virology, and is valuable in the understanding of several eriophyid mite-transmitted diseases of undefined aetiology.

Most importantly, the project has contributed to the development of technologies for disease monitoring, and of broad-based resistance sources for eco-friendly management of this very serious disease on the subcontinent. Characterisation of PPSMV has enabled the development of diagnostic tools for detection of

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*Farmer holding sterility mosaic disease-affected plants in front of resistant ICP 7035 fields*

the virus and identification of its biotypes. This knowledge was used to establish an efficient disease-screening strategy for precise selection of broad-based resistance sources.

Serological and nucleic acid-based assays for the unambiguous diagnosis of PPSMVD were developed. Double-antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) using the penicillinase (PNC) detection system is sensitive, cost-effective and most suitable for application in developing countries. A biological assay using differential pigeonpea types was standardised for the identification of PPSMV strains. This information is essential for the identification of broad-based resistance.

Diagnostic tools and the development of a more efficient virus inoculation method have made it possible to evaluate precisely the form of PPSMVD in germplasm. Several cultivated pigeonpea genotypes tested possess resistance to a mild strain of PPSMV, and fewer genotypes showed resistance to both mild and severe strains. One such genotype, ICP 7035, with broad-based resistance to PPSMVD and with good economic traits, was selected for release to farmers for adoption. Broad-based resistance in several wild *Cajanus* accessions, some of which also possess resistance to fusarium wilt and pod borer, was identified. These accessions are now being utilised in breeding programmes to develop high-yielding pigeonpea genotypes with broad-based resistance to PPSMVD, wilt and pod borer problems.

Sufficient quantities of diagnostic tools (antibodies and oligonucleotide primers) and seed material of promising genotypes and differential cultivars were distributed to the national agricultural research systems (NARS) involved in research on PPSMVD. Seed of promising genotypes, especially ICP 7035, is being multiplied for distribution to plant breeders in NARS and to poor farmers in areas where the disease is endemic.

Participatory plant selection processes with NARS were used to evaluate several cultivated and wild pigeonpea accessions for resistance to PPSMVD under various agro-ecological conditions. This process identified several genotypes in cultivated and wild pigeonpea that have resistance to more than one PPSMV biotype. Seeds of the most promising genotypes were tested on-farm in farmer participatory trials. Pathways were established for dissemination of the technology and products to NARS, NGOs and farmers through participatory research, training courses and farmer participatory trials. These activities led to the identification of high-yielding pigeonpea cultivars with broad-based resistance to PPSMVD, and the supply of seed to needy farmers.

## FURTHER APPLICATION

The new knowledge gained on PPSMV has led to the development of diagnostic tools necessary for its detection, and has laid the foundation for further research to differentiate biotypes. In collaboration with national programmes and extension services, work is being carried out on the effective utilisation of these recently developed technologies and the dissemination of promising seed material for cultivation by farmers (see R8205, page 149).

# Pigeonpea sterility mosaic: application of diagnostic tools for sustainable pigeonpea production in India

**R8205**

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September 2002–December 2004

This project followed on from project R7452, which characterised the causal agent of pigeonpea sterility mosaic virus disease (PPSMVD) and its biotypes, and developed the diagnostic tools needed to select durable, broad-based disease-resistant genotypes suitable for cultivation in diverse agro-ecological regions. Pigeonpea varieties with durable resistance to PPSMVD, combined with integrated management of fusarium wilt and pod borer, will stabilise pigeonpea production and enhance yield potential at no extra cost to farmers. This benefits resource-poor farmers living in marginal areas on the Indian subcontinent, where pigeonpea is a major subsistence crop and women play an important role in post-harvest processing and marketing.

## ISSUES

Following the novel research of project R7452 (page 147), which characterised the pigeonpea sterility mosaic virus (PPSMV) and its biotypes, this project aimed to continue to improve the diagnostic tools and to enhance pigeonpea production through cultivation of elite PPSMVD-resistant varieties. These tools and knowledge are necessary to select durable, broad-based PPSMVD-resistant genotypes suitable for cultivation in diverse agro-geographical regions.

## ACHIEVEMENTS

Three Indian isolates of the virus, from Patancheru (P), Coimbatore (C) and Bangalore (B), were purified and their major properties determined. For PPSMV isolates from Varanasi (V), Uttar Pradesh; Nepalgunj (N), Nepal; Dharwad (D) and Gulbarga (G), Karnataka, severity was determined using differential host genotypes. The B, C, V and N isolates can overcome resistance selected against P, D and G isolates. The resistance-breaking isolates were termed 'highly virulent', and appeared to prevail in southern and northern parts of India, whereas isolates similar to P, D and G were mostly confined to Central India.

A cDNA library of the PPSMV genome was constructed. Several clones were sequenced, amounting to about 30% of the total PPSMV genome. The sequences found no matches during database searches, which limited comparisons for the inference of functional aspects of the genome. The sequence information was used to design a new set of oligonucleotide primers for differentiation of PPSMV-P and C isolates. Enzyme-linked immunosorbent assay (ELISA) and reverse transcription–polymerase chain reaction (RT–PCR)-based diagnostic tools have already been developed, which can be used to detect all PPSMV isolates.

The epidemiology of PPSMVD was studied in peninsular India, and critical factors contributing to inoculum survival during off-seasons were identified. Detailed studies on three PPSMV isolates indicated complexity in distribution of the various isolates. Despite a continuum

*Village-level training: farmers listening to lecture on management of PPSMVD*

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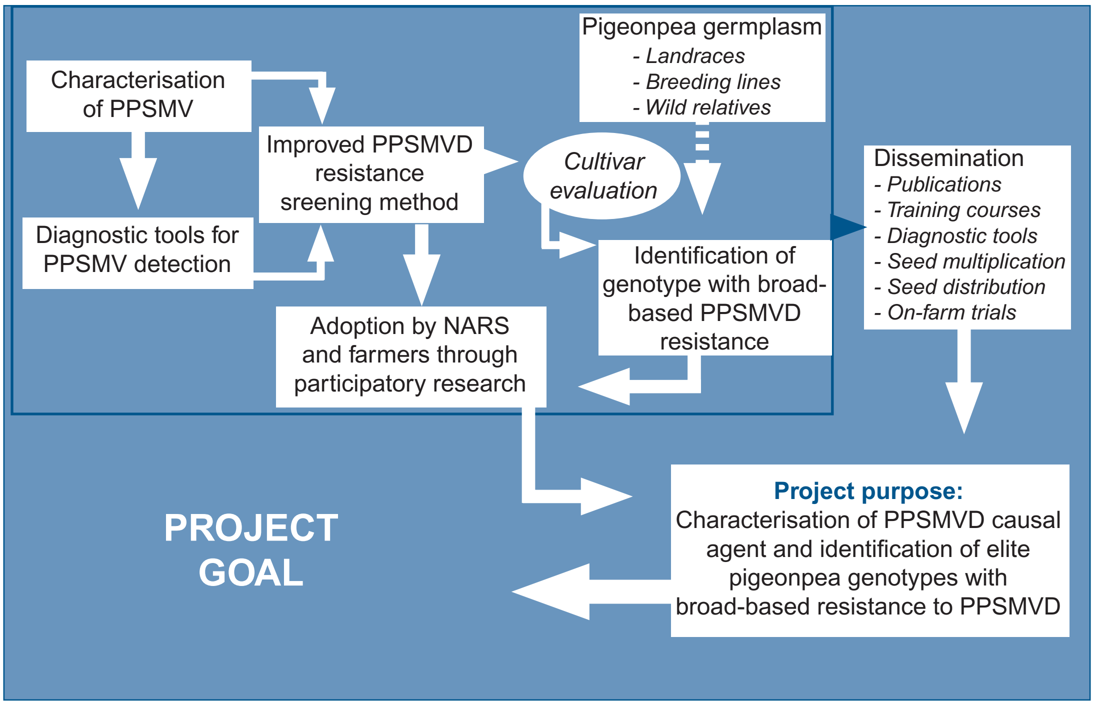
*Participants in training course on virus detection methods and screening for disease resistance*

in pigeonpea cultivation, PPSMV isolates appear to be geographically restricted. This was based on the assessment of isolate virulence using differential genotypes in prevailing regions over several years.

An efficient screening strategy was established for the precise selection of broad-based sources of resistance. This method resulted in the selection of six pigeonpea varieties (ICP 7035, ICPLs 87051, 99050, 96053, 96058 and 96061); six breeding lines (ICPLs 83015, 93087, 93183, 93184, 95020 and 95024); and 15 wild pigeonpea accessions for on-farm evaluation and use in breeding programmes. ICP 7035 has been provisionally approved for release in Karnataka. ICPLs 96058 and 96053 are being evaluated on-station and on-farm for release to farmers. Seed of the promising pigeonpea varieties was multiplied and supplied to farmers and the national agricultural research and extension systems, for adoption and further use in local crop improvement programmes.

Variety ICPL 96058 is being cultivated by farmers in central peninsular India. This variety has been incorporated into the national Initial Varietal Trial Programme through Gulbarga Agriculture Research Station. Variety ICP 7035 had been evaluated for five years in farmers' fields in southern Karnataka, and shows durable, broad-based resistance to PPSMVD. It was evaluated in the disease-endemic zones of Karnataka and Tamil Nadu, where highly virulent isolates are prevalent, and tested on-station in several other states in India, Nepal and China. ICP 7035 can be grown as a vegetable and also for seed. It is being adopted in peri-urban regions in southern Karnataka.

Certain physical and physiological effects of PPSMV on pigeonpea were determined to assess the impact of disease on plant growth and yield. This showed that modification of axillary buds into leaf structures at maturity was the reason for sterility (lack of flower production). In a susceptible genotype the virus invades all parts of the plant, but not the cotyledons. Seeds from infected plants were free of the virus, but were poor in quality with up to 50% reduction in dry weight, and




*Outputs contributing to project goal*

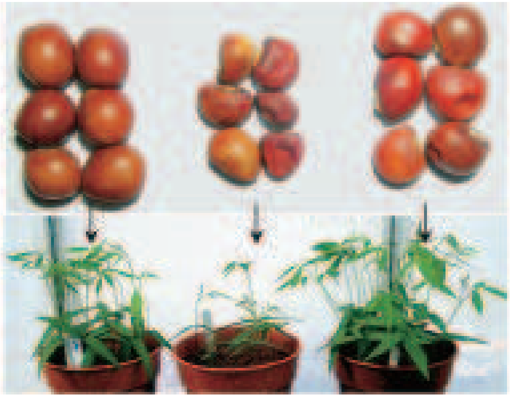
poor germination rate and vigour. The thickness of the epidermal cell wall and cuticle in susceptible varieties was lower than in resistant varieties. This, in combination with scanty leaf hairs on the lower epidermis of resistant genotypes, may contribute to poor vector survival on such genotypes, and consequently to resistance to PPSMVD. The inability of certain PPSMV isolates (e.g. P, D and G) to spread into conductive tissue appears to be the reason for localised symptoms in tolerant genotypes (e.g. ICP 2376) that show chlorotic ringspot symptoms at the site of mite feeding (virus inoculation). However, highly virulent PPSMV isolates (e.g. B and C) can break this tolerance and spread systemically. This feature of ICP 2376–isolate interaction is being exploited to characterise the virulence of various PPSMV isolates.

The technologies developed were transferred to beneficiaries through partnerships with targeted national institutes, organisation of training courses and working group meetings, and farmer participatory trials for genotype evaluation. Partnerships with stakeholders allowed methodologies to be tested and their feedback was instrumental in achieving the targets. Farmers received training in integrated disease and pest management to control PPSMVD, fusarium wilt and pod borer, and in post-harvest seed processing to prevent contamination with storage pests.

Sufficient quantities of diagnostic tools (polyclonal antibodies, PPSMV-IgG-penicillinase conjugate and oligonucleotide primers) and seed material of promising genotypes (ICP 7035, ICPLs 87051, 96058, 96053, 96061) and differential cultivars were distributed to those involved in research on PPSMVD. Seed of promising genotypes, especially ICP 7035, ICPL 96058 and breeding lines, is being multiplied for distribution to farmers and breeders. A laboratory manual incorporating detailed descriptions of various experimental procedures and techniques was published.

## FURTHER APPLICATION

There is potential for further expansion to tackle several key issues:



*The effects of PPSMVD on pigeonpea seeds and germination: healthy plant (left), severely affected (centre) and mildly affected (right)*

- the narrow base of genetic resistance to highly virulent isolates of PPSMV (e.g. C and B isolates)
- development of PPSMVD resistance in short- to medium-maturing (100–160 days) genotypes to escape terminal drought stress (a constraint affecting long- and medium-duration crops in peninsular India)
- upscaling of on-farm activities with more participatory field trials for wider dissemination of promising disease-resistant varieties.

*The project goal – sustainable livelihoods*

# Promoting the adoption of improved ICM technologies in chickpea by poor farmers in Nepal

**R7885**

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April 2000–July 2003

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Chickpea is an important source of protein in Nepal for both poor rural and urban families. Yields of legumes including chickpea have decreased in recent years, primarily due to disease and insect pest problems, and the reluctance of farmers to invest time and money in a crop which increasingly fails. This project aimed to improve, validate and evaluate a complete integrated crop management (ICM) strategy for chickpea on farms; to persuade farmers to adopt the strategy through workshops and farm trials in some of the poorest areas of Nepal; and to promote the strategy widely to the press and other stakeholders. The improved seed and technologies offered were in high demand by farmers, and the project produced evidence to show that the outputs (increased yield of a cash crop) have been translated into significant impacts on livelihood, including improved housing, debt repayment, education costs, clothes and healthcare. The value of the improved seed has been impressive and will benefit farmers in the longer term. An innovative promotional strategy promoted the findings to policy-makers as well as farmers, and used the popular media in Nepal and the UK to publicise the work.

## ISSUES

Chickpea is a major source of protein throughout South Asia; it is versatile and is important for making a variety of products including breads, sweets and biscuits. It also plays a religious role for Hindus. In Nepal, chickpea production has declined severely due to several pest and disease problems increasing in severity. There are tens of thousands of hectares of winter rice fallows where farmers could grow chickpea successfully, and the project aimed to encourage use of this land by demonstrating the viability of the chickpea crop, and by evaluating and promoting technologies that could reduce crop losses.

*Chickpea production boosted using technologies promoted by the project*

Botrytis grey mould (BGM) is a disease that kills chickpea flowers and dramatically reduces yield. Incidence of this disease has increased severely over the past 10 years; in the 1997/98 season, high rainfall and humidity throughout the winter resulted in such high incidence that little seed could be saved by farmers or government agencies, and hardly any locally derived chickpea seed was sown in 1998/99.

The *Helicoverpa armigera* pod borer emerges as a major pest threat where BGM has not occurred, or once BGM has been controlled, because there are pods for the borers to eat. The larva burrows into the pod and consumes the pea, and population explosions of the pest may devastate the crop. The insecticide thiodan (= endosulfan) is widely used to control pod borer, but the quality of the insecticide sold is often poor; farmer health and safety is invariably casual; and there are increasing reports of insecticide resistance in Nepalgunj and further west. A viable alternative to chemical insecticides is the biopesticide *Helicoverpa armigera* nucleo-polyhedrovirus

*BGM infects flowers, causing flower drop and reduced yield (left). The pod borer* H. armigera *burrows into pods and eats the seeds, and can decimate chickpea crops (right)*

(*Hear*NPV). Thus an additional aim of this project was to evaluate and validate NPV in the laboratory, on research stations and in farmers' fields.

Towards the end of the project, livelihood benefits from growing chickpea were estimated with farmers.

## ACHIEVEMENTS

A survey was carried out of the constraints to rabi (post-rainy-season) chickpea production and its impact on farmers' livelihoods. The survey results helped determine the focus of the project, and established baseline data against which the improvements in chickpea production could be assessed.

Based on these findings, an improved ICM strategy was developed and validated that was appropriate for poor farmers in the mid-hills and hillside regions of Nepal. The principal components are:

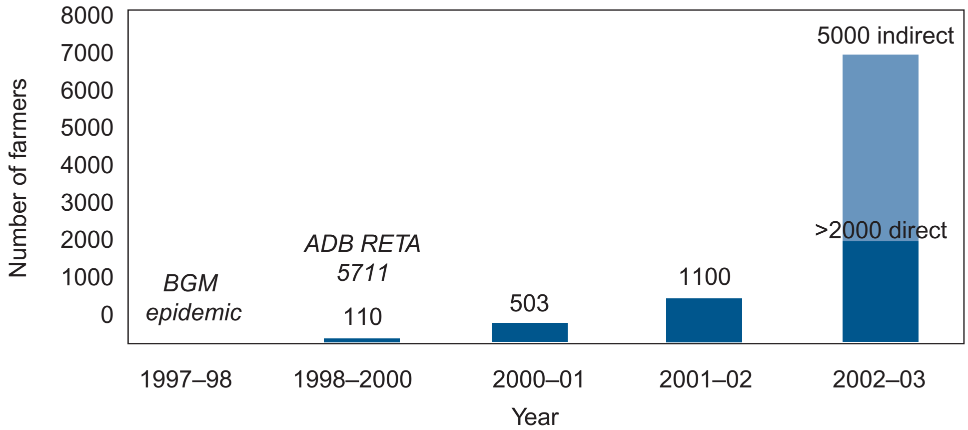
- adoption of an improved cultivar, Avarodhi, which is resistant to fusarium wilt
- use of seed priming
- control of BGM with carbendazim (Bavistin) once a week at flowering when morning mists do not clear
- control of pod borer with one or two sprays of thiodan
- fungicidal treatment of seed with thiram and carbendazim (Bavistin)
- use of *Rhizobium* inoculum
- application of diammonium phosphate fertiliser or farmyard manure
- maintenance of an open canopy by avoiding irrigation and excessive fertiliser application.

New ICM promotion tools were produced and disseminated to hillside farmers in Nepal. These tools consisted of various devices for farmers attending field schools, mainly information sheets describing the nature of constraints to chickpea production and how to manage them.

The project also included the evaluation and validation of *Hear*NPV. Although laboratory studies indicated that chickpea reduced the efficacy of virus application through an interaction between the virus and the chickpea leaf surface, simple formulation ingredients based on milk powder improved the efficacy of *Hear*NPV on chickpea up to threefold when it was sprayed as a mixture onto the leaves. *Hear*NPV was at least as effective as the insecticide thiodan at controlling pod borer, and in many cases was more effective. Efficacy was affected by the variety of chickpea on which *Hear*NPV was used. Avarodhi, the preferred variety for all other agronomic characters, was also the most suitable for optimum NPV control of the pod borer.

Information, support and technologies were provided directly to assist about 3500 farmers over the course of three years, and many thousands more benefited through farmer-to-farmer dissemination. The results were also disseminated via other projects in Nepal which promoted the same technology tools and varieties to farmers (e.g. the DFID Plant Sciences Research Programme project on rainfed *rabi* cropping systems, R8098).

Farmer socio-economic surveys were used to determine the impact on farmers' livelihoods of adopting this ICM strategy. Overall, chickpea yields of participating farmers more than doubled, to 2100 kg/ha, when they employed ICM with improved varieties. The net cost of production decreased from NRs17.5 to NRs9.3 per kg. With a market price of approximately NRs30 per kg, this more than doubles profits from




*Adoption of IPM of chickpea in Nepal, from the 1998 Asian Development Bank (ADB) forerunner project (RETA 5711) to 2003*

this crop. Farmers increased their wealth by an average of US$216 per year by growing chickpea using the technologies promoted by this project.

The impact on livelihoods was substantial – the majority of farmers described improvements in all aspects of domestic life, although the extent of these impacts depended on the size of their holding. One dramatic change was in the number of farmers moving from mud houses to brick houses (5–10%). Many farmers reported paying off debts (22%), with dramatic increases in expenditure on education for children, clothes and healthcare. In one village, Lalbandi in central Nepal, 400 farmers were provided with 1 kg of seed each in November 2002 – enough to sow approximately 13 hectares in total. Owing to the promotion by this project and farmers' increased confidence to expand production, the extent of adoption in 2003 had increased to 110 hectares.

*Farmers' traditional practices produce poor yields (foreground) compared with dramatically improved productivity through ICM (background)*

In this village chickpea is rapidly taking over where, in years before, tomato lay rotting in fields or on roadsides, fetching only NRs2 per kg.

The value of the private sector to the ultimate sustainability of chickpea ICM has not been ignored, and the project team has identified dealers in agricultural inputs, and helped to develop market links with chickpea farmers, especially in Lalbandi and Bardibas. At the end of 2003 an additional 7000 kg of seed (enough to sow 233 hectares) was distributed, along with the management practices promoted, to farmers not previously contacted by the project.

## FURTHER APPLICATION

A follow-up project (R8366, page 155) was established to raise awareness at senior levels in the ministry of the potential of chickpea ICM through an international workshop, that aimed to synthesise the results of this research and experience. The intention was to produce a policy document targeting senior government policy-makers in Nepal and elsewhere in Asia (particularly Bangladesh and India), NGOs, private-sector stakeholders, national agricultural research systems, extension organisations, and international donors and research institutes. Follow-up work was also carried out on the production and use of *Hear*NPV.

# Policy and strategy for improved chickpea ICM in Nepal and South Asia

**R8366**

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April 2004–March 2005

A previous project (R7885) demonstrated that adopting high-yielding chickpea varieties along with an integrated crop management (ICM) strategy increases the income and food security of poor farmers in Nepal. This project continued that work to enable the development of a robust and sustainable strategy for adoption of ICM of chickpea in all suitable areas of Nepal. Awareness of the potential of chickpea ICM was raised through an international stakeholder workshop, and through production of a policy document targeting senior government policy-makers in Nepal and elsewhere in Asia (particularly Bangladesh and India), NGOs, private-sector stakeholders, national agricultural research systems, extension organisations, and international donors and research institutes.

## ISSUES

A robust, cost-effective and efficient ICM strategy for increased chickpea production, based on environmentally benign pest management technologies, was successfully validated and promoted on smallholder farms in Nepal under the forerunner CPP project R7885 (page 152). The ICM strategy required that farmers adopt the improved cultivars Avarodhi or Tara (good yield and tolerant to fusarium wilt), seed priming, judicial fungal and insect control using available pesticides or biological pesticides (*Helicoverpa armigera* nucleopolyhedrovirus, *Hear*NPV), *Rhizobium* treatment in deficient areas, and management of sowing density, fertiliser inputs and water to prevent dense canopies. Uptake of the chickpea ICM strategy in the areas of Nepal targeted was widespread and profitable for farmers. It has been estimated by NARC that this approach could be extended to more than 100,000 farming households in Nepal, and larger numbers still in Bangladesh and India, where yields are similar to those in Nepal. The technology could be adapted for Pakistan and Afghanistan, and also East Africa where there is increasing interest in the potential of pulse legumes. This work aimed to identify and synthesise lessons from project R7885 to enable the development of a more robust and sustainable strategy and to broaden the adoption of chickpea ICM across Asia.

*Filling a sprayer with* Hear*NPV*

## ACHIEVEMENTS

The principal activities were based around discussions, consultations and meetings that focused on the synthesis of lessons learned and the development of a strategy for broad upscaling of the technologies in Nepal, while maintaining farmer field schools set up by the previous project, and distributing information to assist more farmers to redevelop their chickpea crop. Issues addressed included:

- how components of the chickpea ICM strategy in Nepal could be embedded in national

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programmes, especially in mid-western and far-western Nepal
- the efficacy of chemical-based pest management technologies for insect and disease management (insecticide resistance/tampering with chemicals/production quality/cost)
- the cost and feasibility of farmer mini-kits as a simple and workable implementation and extension strategy for the MoAC
- consolidating knowledge and facilitating key relationships between private sector, farmers, and non-governmental and government officers
- the acceptability to farmers of biological pesticides such as NPV, and the feasibility of importation or local NPV production.

A workshop was held in Kathmandu in November 2004 to raise awareness of, and define a strategy for, countrywide uptake of chickpea ICM technologies. This was attended by up to 80 participants from South Asian countries, including Bangladesh and India, to help raise awareness beyond Nepal.

The meeting was covered by various media including the evening news on Nepal TV and national newspapers (*Rising Nepal*: 'Commercialisation of agriculture stressed', 18 November 2004, p. 1; *Kathmandu Post*: 'Enhance productivity to promote agriculture', 18 November 2004, p. 3). Presentations on scientific and livelihoods aspects of upscaling technologies, made by 20 scientists over the course of two days, were published as the Workshop Proceedings.

Lessons learned from the previous project (R7885), and from similar projects in Nepal with a goal to achieve broad uptake and impact, were synthesised through group discussions with policy-makers, extension workers and scientists to ensure that scaling up of chickpea ICM in Nepal is well considered and well planned.

*Farmers learning to spray NPV effectively*

One of the principal outputs of the workshop was a policy strategy for large-scale uptake of chickpea ICM in Nepal. Its key findings are:

- chickpea is a crop that can compete with alternatives; it is highly profitable when grown with appropriate technology and improves the livelihoods of poor farmers
- markets *per se* are not a limiting step for the nationwide expansion of improved chickpea production in Nepal (most chickpea consumed in Nepal is still imported), but some aspects of marketing need to be addressed
- complementarity between research and extension organisations in Nepal will be important to enable joined-up extension services and technology support
- seed storage is currently a low priority for both farmers and extension services, and needs greater focus and investment
- pesticide quality and insecticide resistance need monitoring
- the infrastructure and policy/legislation to support biological alternatives need developing
- agricultural knowledge dissemination to farmers needs updating and improving
- there should be more farmer self-help involvement in seed multiplication.

Stakeholders, including NGOs and farmers who attended the November 2004 workshop, were made aware of novel funding strategies currently being implemented by the Government of Nepal under the guidance of the Agricultural Perspective Plan Support Programme for the decentralisation of agricultural development funds to Local Initiative Funds and District Extension Funds.

## FURTHER APPLICATION

A follow-on project (R8427) has the principal aim of ensuring that ICM of chickpea in Nepal, with its proven success and positive impact on farmers' livelihoods, becomes embedded in the national agricultural strategy of Nepal. It aims to achieve this through stewardship of the adoption of the outputs of project R7885 into policy and strategy through training, education and development of tools such as mini-kits, to promote its adoption. By establishing marketing links and networks for community-based and private-sector initiatives, this project will help ensure sustainability and develop wealth-creating environments for stakeholders. Through careful targeting of efforts, ICM of chickpea could be established as normal farmer practice throughout mid-western and far western Nepal – the poorest areas where aid has previously had little impact.

# Sustainable control of cotton bollworm in small-scale cotton-production systems

**R7813**

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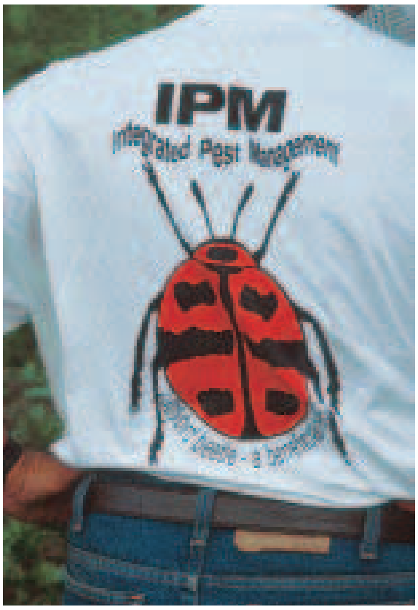
April 2000–March 2004

See R6734, R6760, *Perspectives on Pests 1996–2000*, pp. 95–97

Insecticides currently account for around 45% of cotton-growing costs for over 30 million small-scale producers in Asia at a cost of US$811 million each year. In order to reduce the financial and environmental impact of cotton insecticide use, this project built on recent work in India to advance farmers' ability to use insecticides appropriately for control of cotton bollworm in India, Pakistan and China. The project has provided detailed, practical recommendations to empower farmers to adopt insect resistance management, and has developed easy-to-use insecticide quality and resistance detection kits. Direct impact from the village programme in 2004/05 is a net benefit to participating farmers of US$11 million. This project provides UK input into a much larger (US$4 million) CFC project.

## ISSUES

Across Asia, approximately 30 million small-scale cotton producers endeavour to support their families on less than two hectares of land, with the cotton crop often being their only source of income. Farmers face devastating attacks from pests, in particular the voracious cotton bollworm caterpillar (*Helicoverpa armigera*), which not only damages cotton but also attacks many food crops. India produces 2.5 million tonnes of cotton each year, sustaining the livelihoods of over 17 million people but, because of the increasing cost of pest control, cotton has become less and less profitable. In total *H. armigera* attacks 181 host plants, including 69 crop species, and causes annual losses worth over US$540 million in India.




*Promoting IPM*

The threat of cotton bollworm devastation has increased dramatically in recent years. Through over-use of pesticides and poor spraying techniques, the pest has developed resistance to most of the available insecticides. Farmers continue to borrow money to buy more chemicals (both toxic and expensive) and to spray ever more frequently. The net results are decreasing effectiveness against the pest as resistance develops, environmental hazards, and farmers spiralling into debt.

## ACHIEVEMENTS

Building on previous CPP projects (R6734, R6760), work was carried out to demonstrate to farmers that, with careful timing of insecticide applications, fewer applications can manage cotton pests better and prevent the development of pest resistance, while natural enemies are maintained. The farmer benefits by purchasing less pesticide and by reduced hazards from pesticide application. The insecticide resistance management (IRM) technology promoted to farmers aims to provide simple, practical principles in a participatory manner. Only materials available off-the-shelf are recommended, and simplified bollworm scouting methods have been introduced.

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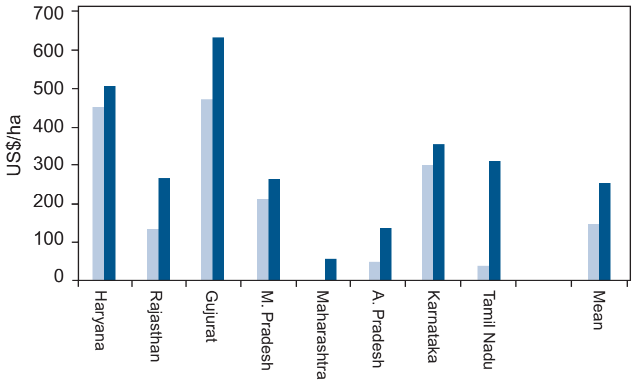
YANG, Y., WU, Y., CHEN, S. *et al.* (2004) The involvement of microsomal oxidases in pyrethroid resistance in *Helicoverpa armigera* from Asia. *Insect Biochemistry and Molecular Biology* 34: 763–773.

The use of resistant varieties reduces the need for scouting of sucking pests. IRM aims to eliminate the application of early insecticide sprays in order to build a good ecosystem necessary for bollworm control. The choice of insecticides used is based on their selectivity and a use-alternation strategy. The aim is to eliminate farmers' dependence on experts (researchers/extension workers) by training them to be managers of pests, predators and parasitoids. This project's specific contributions were as follows.




*Net income from cotton (US$ per ha) 2003–04 (light bars, control farmers; dark bars, IRM farmers by Indian State; north on left, south on right)*

- Support from UK scientists in the development of rapid 'dip-stick' test kits for insecticide quality of major chemicals. These are now being patented for the benefit of poor farmers who are otherwise at the mercy of pesticide dealers.
- A decision tool aiding the selection of appropriate and effective pesticides that cause minimal environmental damage, summarising all published results for all insecticides used for cotton bollworms globally.
- Collaborative work between UK, Indian, Chinese and Pakistani scientists at Rothamsted Research, which has definitively established the causes and patterns of insecticide resistance to the major pesticide groups (pyrethroids, organophosphates, carbamates and cyclodienes) across Asia. This work has enabled the most effective sequence of non-cross-resisted insecticides to be worked out for individual areas.
- This improved understanding has fed into the national cotton extension programmes in India, China and Pakistan. In India the methods developed under this and the earlier projects have been demonstrated to farmers on an increasing scale. Funding is now entirely from the Government of India. In 2003–04 it covered 10 cotton states, with 27 districts, 331 villages, 5372 core farmers and 18,545 farmer participants in the programme. Average insecticide use declined by 56%, yield increased 24%, and consequently net income by US$107 per ha or 74%. Health and social benefits among participating farmers are also being realised.
- Strategies to mitigate early-season damage while conserving natural enemies include the use of jassid-resistant genotypes, seed treatments, and planting cowpea, African marigold or castor. Some jassid attack discourages *H. armigera* without affecting yields.

In the first bollworm control 'window' (60–90 days after sowing), which aims to suppress the first generation of *H. armigera* while minimising the effect on beneficial practices include: scouting (threshold 0.5 larvae per plant); use of biological controls such as *Trichogramma*, neem and *H. armigera* nucleopolyhedrosis virus; the use of insect growth regulators such as novaluron and lufenuron where available; and use of the insecticide endosulfan, which is less damaging to beneficials.

In the second bollworm control window (90–120 days after sowing), to protect boll formation by controlling the mixed instars of overlapping *H. armigera* generations, practices include: scouting (threshold one larva per plant); use of the insecticides spinosad and indoxacarb where available, or the more widely available quinalphos/chlorpyriphos and profenophos (early use of these chemicals should be avoided as they disrupt beneficials, and use of broad-spectrum insecticides such as monocrotophos and acephate should be avoided). In the third window (110–120 days after sowing), if insecticides are necessary at all, pyrethroids should be used as they retain efficiency against other bollworm species and insect pests present at that time.

Innovative extension methods for these strategies included a national street play contest, with the best play performed all over the country by professional teams; and a short film to be displayed all over the country. Farmer manuals have been printed in local languages, and a more comprehensive handbook of bollworm control is in preparation.

## FURTHER APPLICATION

Resistance to insecticides in the pest population is constantly changing. The project has supported the key laboratories in China, Pakistan and India, which provide the national recommendations on pesticide use in cotton pest control. With the inputs of scientists from China, Pakistan and India, work will continue on the biochemical and genetic characterisation of insecticide resistance across the region. Project results are now being applied as a matter of national policy in all three countries. Preventing the development of resistance is an important aspect of the deployment of transgenic, insect-resistant cotton (now being grown in China and India and under trial in Pakistan). The project laboratories are continuing to play a leading role in the development of resistance-management strategies for these important advances.

# Rice sheath blight complex (*Rhizoctonia* spp.): pathogen epidemiology and management

**R7778**

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June 2000–November 2003

See R6643, *Perspectives on Pests 1996–2000*, p. 77

Rice sheath blight is becoming an increasingly important disease in Bangladesh, partly due to the intensification of rice production practices. Currently there are few available options to manage the disease effectively. No sources of strong resistance to the disease have been identified, and the epidemiology of sheath blight is still not fully understood. This project has contributed to the knowledge base by documenting the seasonal distribution of the diseases comprising the sheath blight complex and recording the distribution of the three causal agents (*Rhizoctonia solani*, *R. oryzae* and *R. oryzae-sativae*). Varieties with moderate resistance to sheath blight have been identified, and soil amendment practices for disease management evaluated. Farmer surveys have confirmed that sheath blight is regarded as a serious constraint to production, and that farmers are willing to try out resistant varieties and other recommended practices. This fundamental research, and the development of diagnostic tools, have provided a sound basis for BRRI to develop a strategy for improved sheath blight management.

## ISSUES

In Asia the average population growth rate is estimated to be 2.4% per annum from 1987–2005 and 1.3% from 2006–30. An estimated 800 million to one billion tonnes of rough rice will be needed annually by 2030. Rice sheath blight (*Rhizoctonia solani* and related species) is one of the most destructive diseases of rice, and is a major constraint to production in many parts of Asia, including Bangladesh. The disease is endemic in rice-growing regions.

The pathogen survives as sclerotia in soil and in debris from previous crops, and is most severe when sclerotia and debris float to the surface of flood water and initiate infection on the lower leaf sheaths. There have been reports of the disease spreading through airborne basidiospores, and through seedborne inoculum. Differences in aerial and soil populations of the pathogen have also been reported. The versatility of the pathogen, its competitive saprophytic ability, and the prolonged survival of the propagules in soil make this disease extremely difficult to control. In India, *Rhizoctonia oryzae* (sheath spot) and *R. oryzae-sativae* (aggregate sheath spot) have recently been associated with rice sheath diseases (R6643). In Bangladesh there is a lack of knowledge of the occurrence and

*Plot tests to assess the effects of organic amendments on rice sheath blight*

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epidemiology of these pathogens, and a need to develop effective disease control measures.

Modern varieties are grown in over 50% of the rice area in Bangladesh. The susceptibility of modern varieties to several major pests and diseases is a common reason for production losses, and very few modern varieties are resistant to sheath blight. As a consequence, the impact of the disease will increase with the expected expansion of rice cropping.

## ACHIEVEMENTS

A socio-economic survey of 400 farm households (100 each) from Bogra, Rajshahi, Comilla and Gazipur districts was conducted, and the data are archived centrally at BRRI (Pathology and Biometrics Divisions), Gazipur. This database is a compilation of information related to rice production, and pest and disease management with particular reference to *Rhizoctonia* sheath diseases.

Sheath blight, locally described as *kalopocha*, *pochon* or *kholpora*, is considered the major rice disease by farmers in all four districts surveyed. Moderate and high disease levels were reported by up to 73% and 11% of farmers, respectively, during the Aman season, and by up to 60% and 16% during the Boro season (see Glossary, page vii). Losses based on farmers' yield estimates were around 30–32% in both Aman and Boro. However, in the Boro season, farmers in Bogra and Comilla reported higher losses than those in Gazipur and Rajshahi. High-yielding cultivars such as BR11 and Swarna are widely used and are highly susceptible to the disease.

Farmers practising wider spacing and using different varieties generally reported lower disease levels than those using lesser or haphazard spacing, and varieties with multiple tillers. Some farmers had been misled into non-target use of pesticides and improper spacing or sowing to control diseases, and were not aware of the negative effect of overdoses of nitrogen fertiliser on sheath blight severity. Over 90% of farmers were willing to adopt improved varieties and technologies such as amendments and/or biocontrol agents. Thus there is both a crucial need and excellent potential for uptake, adoption and impact through supporting participatory research/validation and training/demonstration programmes for rice farmers.

The occurrence and severity of sheath blight (*R. solani*), sheath spot (*R. oryzae*) and aggregate sheath spot (*R. oryzae-sativae*) were surveyed in four districts during 2001–03 in rainy-season transplanted Aman 2001 (T-Aman 01); winter Boro 2001–02, and T-Aman 02 for all the locations, with an additional monitoring in T-Aus at Tanore Upazilla, Rajshahi. At each location, 72 fields were assessed during various crop stages.

Sheath blight was the most prevalent disease (20.8%) in all the locations and seasons, with low-level incidences (2%) of aggregate sheath spot and sheath spot. The incidence and severity of sheath blight varied significantly among seasons and locations. The interaction effect between locations and seasons was also significantly varied. Among the seasons, T-Aus was the most favourable for sheath blight disease, followed by T-Aman and Boro. Highest incidence (48.4%) and severity (33.2%) of sheath blight was recorded in T-Aus (Rajshahi). In the Boro season, the severity of sheath blight was lower than either T-Aman or T-Aus. Among the locations, the incidence of sheath blight was comparable at Bogra, Comilla and Gazipur, with a higher level of incidence in Rajshahi, and the mean severity index was also highest in Rajshahi (16.6%).

Wide-scale adoption of highly susceptible cultivars and intensification with monocrop rice cultivation appeared to be the major causes of high sheath blight levels. However, sheath blight disease was least in the rice–potato cropping pattern. Irrespective of location, season and year, vertical spread and severity of the disease increased as the crop approached maturity, and the overall yield loss was estimated to range between 136 and 762 kg/ha.

Molecular diagnostic tools have been designed, tested and developed, including primers for the polymerase chain reaction (PCR) with enhanced specificity to the three *Rhizoctonia* species, PCR protocols, and DNA extraction methodologies for rapid and reliable analysis of fungal and plant specimens and pathogen/ disease diagnosis. Utilisation of these tools in combination with intensive disease surveys confirmed *R. solani* causing sheath blight as the dominant pathogen (more than 80%), and importantly identified wide occurrence of the aggregate sheath spot pathogen *R. oryzae-sativae* (48%), either singly or with *R. solani*, in rice production systems in Bangladesh. Use of independent molecular markers such as amplified fragment length polymorphisms and simple sequence repeats revealed considerable genetic variation among *R. solani* populations with no specific relationship to the location or host gene pool. A collection of well characterised isolates that form a baseline for long-term monitoring and use in resistance screening work has been established.

Sclerotia were isolated from more than 90 soil samples from Bogra, Comilla and Gazipur, and in general over 60% of the sclerotia were not viable. Within viable populations, recovery of *R. solani* ranged from 50–90%, while only around 9% of *R. oryzae-sativae* recovered. Pathogenicity testing of 32 *R. solani* isolates from both plant and soil sources from four sites revealed significant variation in their aggressiveness, irrespective of the source and location, underlining the importance of using appropriate isolates in screening tests. Interestingly, comparative molecular analysis of up to 40 *R. solani*

Carrying out a disease survey for the occurrence and severity of sheath blight, sheath spot and aggregate sheath spot

isolates from corresponding plant and soil samples revealed more differences than similarities. This clearly emphasises the need to investigate further, and to take into consideration the relative importance of the number of pathogen infection units present in soil versus the spread of infection within the canopy in implementing disease control measures. Further, inoculation with more than one *Rhizoctonia* species combinations under artificial conditions influenced sheath disease severity. The potential impact of a high level of co-occurrence of *R. solani* and *R. oryzae-sativae* also needs to be investigated further in disease development and management.

A total of 15 organic amendments were tested for control of sheath blight in T-Aus, T-Aman and Boro during 2002–03. In Comilla, among the organic amendments tested, compost, pulse bran and rice bran showed the better results, while in Gazipur *urmoi* (*Sapium indicum*), *bishkatali* (*Polygonum hydropiper*) and compost showed good indications for the control of sheath blight and increased yield. In Rajshahi, pressed mud, sawdust and rice bran reduced disease severity. Thirty rice varieties/lines were artificially screened for their reaction to *R. solani* isolated from sheath blight-infected rice plants. None of the entries showed a resistant reaction. Sixteen entries showed a moderately tolerant reaction (<5), and the rest of the entries, including exotic and native cultivars, appeared highly susceptible to sheath blight.

Infected plant samples were assayed for the presence of antagonistic bacteria. Out of 119 samples tested, 19 showed fluorescent bacteria from which 139 colonies were isolated. Among these, 38 colonies showed a high level of antagonism against the sheath blight pathogen *in vitro*.

The project worked in close collaboration with BRRI staff, and for both socio-economic and disease surveys, enumerators were trained centrally at BRRI leading to a skill base that can be utilised by these organisations in future research activities. A stakeholder workshop was held at BRRI-Gazipur with participants from interested institutions. Close links were established with a range of organisations involved in rice sheath disease research, leading to student placements and exchange of knowledge and material.

## FURTHER APPLICATION

An extension project (R8446) is aiming to ensure the molecular biotechnological tools and the appropriate knowledge for their effective use are established at BRRI, building on the molecular laboratory of the DFID–PETRRA (Poverty Elimination Through Rice Research Assistance) Project. This might be done in conjunction with further assistance to BRRI in the area of varietal characterisation and promotion, and in the development of biocontrol agents. Closer links with the International Rice Research Institute are envisaged in order to achieve maximum impact.

# Ecology and management of rice hispa (*Dicladispa armigera*) in Bangladesh

**R7891**

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November 2000–January 2005

Rice hispa is a serious pest of rice in Bangladesh and other rice-growing countries in tropical Asia, causing losses of up to 50% in some badly affected areas. This project carried out socio-economic studies that clarified the acceptability and economic basis of IPM practices currently promoted by the DAE for hispa management. This research has gained a better understanding of the population dynamics of rice hispa, and of the role of natural enemies and abiotic factors as mortality agents. The new results will add to the DAE's IPM farmer training programme through streamlining cultural controls and promoting conservation of natural enemies. The state (DAE and BRRI) aims to develop its support to field extension workers/ farmers through improved monitoring and forecasting tools. The potential of mycopesticides is being followed up by connecting with more advanced technology that has been developed in India.

## ISSUES

Rice production is crucial to the Bangladesh economy. Approximately 75% of cropped areas and 83% of the total irrigated area are devoted to rice cultivation, and an estimated 60–70% of the agricultural labour force is employed in rice production, processing, marketing and distribution. Despite varietal improvements, there is much potential to increase the rice yield by reducing pest and disease damage. In some areas, intensification through the introduction of high-yielding varieties and the use of insecticides has led to widespread rice pest outbreaks and the emergence of secondary pests. These outbreaks are now understood to be induced by the removal of generalist predators from the system through the application of insecticides.

The rice hispa (*Dicladispa armigera*) is an increasingly important outbreak pest in rice cropping systems in Bangladesh, and appears to be associated with intensification of production. In Bangladesh, yield losses have been estimated as 40–50%, and the problem is intensifying. This pest poses particular challenges for ecological research because of its episodic occurrence and migratory behaviour. An understanding of its population

*Hispa damage and adult* Dicladispa armigera

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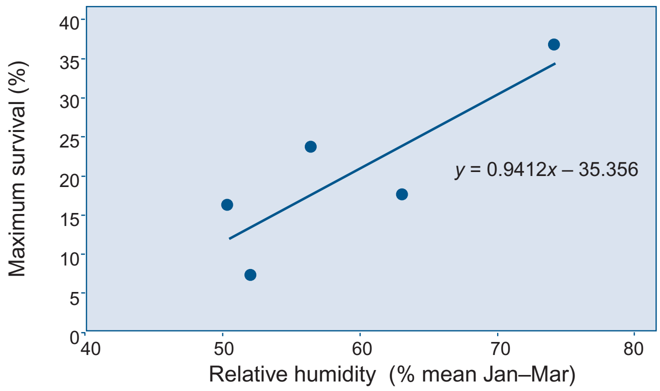


*Field study results on the relationship between yearly maximum rice hispa survival and mean minimum percentage relative humidity for January–March of the same year (all sites combined).*

dynamics and natural mortality factors, and of options for its control, are needed to develop appropriate, sustainable control measures in the context of a rice IPM strategy in Bangladesh.

## ACHIEVEMENTS

Socio-economic studies confirmed that farmers rate insects as the worst production problem; hispa is viewed as second only to stem borer as a constraint (see R8026, page 165). Advice on IPM promoted by the DAE was found to be generally sound, and the DAE's IPM training programme for farmers (under its Strengthening Plant Protection Project, SPPS) provides a good basis for equipping farmers with the right knowledge. In general, insecticides are the most popular tool and there is no evidence of abuse in their current use; however, mycopesticides may provide an alternative. But the economic basis of some of the cultural controls used is questionable, and DAE needs to factor this into the development of its training programme. Farmers strongly support current state interventions, such as provision of sprayers and sweep nets.

Ecological research focused on understanding the broad patterns of rice hispa distribution, abundance and survival, and the key factors affecting natality and mortality, using historical data and information from field studies and current geographical surveys. In summary, a clear relationship was seen between hispa numbers and some abiotic parameters, particularly humidity values in the previous winter.

Surveys have shown that hispa is present at very low levels of incidence throughout most of the lowland rice area, which means that all these areas are probably at risk from locally based outbreaks as well as invasions from remote areas. Greater vigilance is needed in areas outside the southern region of Bangladesh, which is currently assumed to be hispa's winter endemic range. Simple GIS models have been explored to predict hispa risk areas on a more local basis. The analysis of the historical data has added some key points to this baseline work, as follows.

- Hispa outbreaks appear to build up over two-year periods. An increase in hispa infestations in the more southerly districts in one year is sometimes followed by more generally high hispa infestations over all hispa-prone districts in the following year.
- Cropping pattern and hispa distribution are related. Districts with a combination of a low proportion of Aman single cropping *and* a high proportion of Boro–Aman double cropping were never hispa-prone (see Glossary, page vii).
- Within a district, hispa abundance in successive crops in the same season was often (but not always) correlated, so hispa abundance in the Boro season is a potential predictor of abundance in the Aus and Aman seasons.
- Years with high winter humidity and high winter and summer temperatures tend to have higher hispa abundance. However, the climate data did not explain why some districts were more hispa-prone than others.

Hispa abundance was predicted to be above average if humidity

**Results of hispa abundance prediction for Barisal district based on minimum humidity in current and previous years**

| Year | Humidity minimum (month average) | Hispa abundance* | Predicted hispa abundance |
|---|---|---|---|
| 1983 | 57 | 0 | 0 |
| 1984 | 64 | 1 | 1 |
| 1985 | 62 | 1 | 1 |
| 1986 | 63 | 0 | 0 |
| 1987 | 66 | 1 | 1 |
| 1988 | 64 | 1 | 1 |
| 1989 | 58 | 0 | 0 |
| 1990 | 70 | 1 | 1 |
| 1991 | 64 | 1 | 1 |
| 1992 | 59 | 0 | 0 |
| 1993 | 64 | 1 | 1 |

*Greater or less than long-term trend.

*Host feeding trials for rice hispa*

in the preceeding winter was (a) ≥64%; or (b) ≥62% *and* 64% or more in the previous winter. Otherwise hispa abundance was predicted to be below average. Predictions for Barisal over the period 1983–93 were 100% correct (see table).

Field studies confirmed the importance of winter relative humidity and also of river flooding as mortality factors. Further work is needed in this area to develop better monitoring schemes and to build on the GIS modelling already under way.

Other research indicates that hispa can feed and reproduce on rice of a wide range of ages, and on a number of common weed species. IPM training will now highlight the significance of alternative hosts.

*Experiments on rice hispa feeding: choice (top) and no-choice (below), BRRI, Gazipur (photo: BRRI)*

Life-table studies show that insect natural enemies have an important impact, and one species of parasitoid (*Trichogramma zahiri*) appears to be density-dependent and therefore may be a regulatory factor. Thus the conservation of natural enemies needs to be built into IPM training, although the episodic nature of hispa outbreaks makes augmentation technologies using insect parasitoids difficult to implement.

But there are good possibilities for the development of a mycopesticide (for example, one based on *Beauvaria bassiana*), by linking with more advanced research in India – collaborative interactions have already begun. A mycopesticide is the only viable alternative to insecticides.

A national workshop consolidated the project outputs into an agreed plan that will build on the current IPM effort in Bangladesh. The main action required is for the DAE to develop IPM for farmers by factoring in the project results.

## FURTHER APPLICATION

The project results contribute directly to further development of the existing DAE–SPPS IPM training programme for hispa. There is still some way to go in developing IPM packages acceptable to farmers, in terms of both further technologies – especially mycopesticides – and ensuring that cost–benefit ratios of IPM measures are attractive to farmers. Further research is needed on monitoring and forecasting models for hispa/rice pests.

# Commercial adoption of pheromones as a component in ICM of rice in Bangladesh

**R8026**

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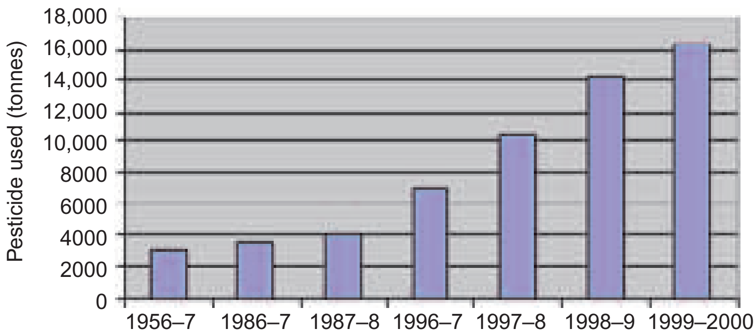
September 2001–October 2003

Bangladesh has been enormously successful in increasing its rice production in an effort to attain self-sufficiency. This has been largely achieved through an increase in acreage of the Boro crop (high-yielding, irrigated, post-rainy-season rice), with the BRRI introducing a range of high-yielding varieties to replace the more traditional deep-water varieties. However, insecticide use is also increasing, at the expense of both farmers and the environment. To assist local institutions and companies to work with farmers to reduce insecticide use and promote integrated crop management (ICM), this project aimed to adapt existing pheromone-based control methods (specifically for rice yellow stem borer) to local conditions, and incorporate them into the ICM programme promoted by Syngenta Bangladesh Ltd through its farmer field school programme.

## ISSUES

There is significant evidence that insecticide use in Bangladesh is increasing dramatically (see below). While application on rice is still significantly less than in other countries in the region, farmers perceive rice stem borers as a significant threat to their crops, and are applying pesticides where they are not actually necessary, at high cost to themselves and the environment. Because the stem borer larva is actually inside the stem of the rice it is well protected from pesticides, so farmers have to use relatively toxic systemic granular pesticides to control the pest. These pesticides are becoming redundant because of the development of resistance to them and, more importantly, because governments are becoming aware of the negative environmental and health aspects associated with the use of these compounds, so there is a now an urgent need for the development of alternative control technologies. There is growing awareness of the social and environmental costs of using pesticides such as organochlorines in Bangladesh, where agribusiness companies, such as Syngenta in particular, are keen to encourage and promote sustainable production through the development of new crop protection technologies.

Mass trapping of stem borers is a simple technology in which male stem borer moths are caught in traps baited with the female pheromone. Pheromones are naturally occurring compounds produced by insects that act as messages to other insects. Adult female yellow stem borers (*Scirpophaga incertulas*) attract their mates with a pheromone




*Pesticide consumption in Bangladesh shows a 235% increase over 1996 levels*

## SELECTED PUBLICATIONS

CORK, A., KAMAL, N.Q., ALAM, S.N., SAHA CHOUDHURY, J.C. and TALEKAR, N.S. (2003) Pheromones and their applications to insect pest control. *Bangladesh Journal of Entomology* 13: 1–13.

CORK, A., ILES, M.J., KAMAL, N.Q., CHOUDHURY, J.C.S., RAHMAN, M. and ISLAM, M. (2005) An old pest, a new solution: commercialising rice stem borer pheromones in Bangladesh. *Outlook in Agriculture* 34, 181–187.

WREN MEDIA (2003) Pheromones – the trappings of sustainable pest control? *New Agriculturist Online*, 7 July 2003. www.new-agri.co.uk/03-4/develop/dev03.html

and this can be exploited in a pest management strategy by developing a synthetic pheromone blend and a lure and trapping system, which attract and trap male moths. If female yellow stem borers cannot mate then the pest population can be checked. Building on work conducted by scientists in India, Syngenta has been collaborating with BRRI and NRI to adapt mass-trapping technology for use in Bangladesh.

*Yellow stem borer adult (left); its larvae cause white head damage (below)*

## ACHIEVEMENTS

A wide range of trap designs, pheromone blends and concentrations were tested with farmers in their fields in Comilla and Mymensingh districts in 2001–03, alongside a socio-economic study of farmers' resources, constraints and perceptions to ensure the resulting technology was appropriate for adoption.

A robust, cost-effective and efficient trapping system for male yellow stem borers was developed, using an optimised female sex pheromone lure and trap design. A series of trials designed to optimise trap design, pheromone dispensers and pheromone blends resulted in the identification of a trapping system that was effective, relatively inexpensive and easy to use. A plastic sleeve trap was found to be more effective than other trap types at higher levels of catch, and was unaffected by the weather.

On-farm, large-scale mass trapping trials demonstrated that 20 traps per hectare were sufficient to reduce male yellow stem borer populations significantly. The trials provided good evidence that mass trapping could significantly reduce the level of mating, with consequent reductions in larval progeny.

Nevertheless, the level of control achieved by mass trapping in these trials did not have a measurable impact on yield. This was due to the low level of stem borer damage observed in both treated and untreated plots, and because of the presence of other stem borer species.

The research confirmed that, despite low levels of *S. incertulas* infestation being recorded in all seasons, other species did not increase to fill the niche. The reasons for the low infestation levels are not known, but broadly reflect those found in a previous CPP project (R7296) in which, over the course of four seasons, rice stem borer infestations did not exceed the economic threshold at any site.

Extensive sampling between and within seasons demonstrated that

**Optimisation of pheromone trap design***

| Trap design | Pheromone dose (μg) | Mean catch per trap per night† | SE |
|---|---|---|---|
| Delta | 1000 | 0.41 | ± 0.16 ab |
| Sleeve | 1000 | 0.72 | ± 0.17 ab |
| Sticky plate | 1000 | 0.85 | ± 0.28 ab |
| Open-delta | 1000 | 1.15 | ± 0.29 b |
| Plastic cylinder | 1000 | 0.47 | ± 0.11 ab |
| Plastic pot | 1000 | 0.22 | ± 0.07 a |

*Doulatpur, Laksam, Comilla District, T. Aman 2001, four replicates, 42 nights.
†Means followed by the same letter in a group are not significantly different $P < 0.05$ by Newman–Keuls multiple range test on $\log(x + 1)$ transformed data.

rice stem borers in Bangladesh constitute a species complex of *S. incertulas*, *Sesamia inferens* and *Chilo polychrysus*. The relative abundance of each species varied markedly within and between seasons, with *S. incertulas* appearing early in the season, often to be replaced by *S. inferens*.

Despite the high intensity of rice cultivation, yellow stem borer was found to be of economic importance only in the Aman season. Based on project results, stem borer control is not recommended in Aus and Boro season crops.

The project contributed significantly to the understanding of how mass trapping can be developed and implemented as a method of controlling field crop pests. The new knowledge has already been utilised in a related DFID Competitive Research Facility project for control of brinjal shoot and fruit borer, *Leucinodes orbonalis*, in India and Bangladesh (R7465C), and will have significant value for other target pest species.

Farmers' perceptions of damage, however, are not necessarily in accordance with the scientific evidence. The key issue for insect pest management in rice in Bangladesh is how to encourage farmers to target their interventions against stem borers more efficiently and in an environmentally friendly way. The socio-economists conducted a very useful study that will help to guide the strategy for promotion of the pheromone technology. Critical considerations such as product pricing and training and information provision were addressed in depth and suitable recommendations were made.

Despite information gathered on the low levels of stem borer infestation, in surveys carried out by this project, over 90% of farmers identified yellow stem borer as the major pest of rice, with 58% of respondents citing damage levels in excess of 10%. Farmers had a good knowledge of the effect of stem borer larvae on rice, but did not distinguish between species. Many farmers are not aware that the yellow 'worm' inside the rice stem that they recognise as a pest will mature into a moth, but they do know that if they do not control it the rice grains that form will be empty (white heads) and have no nutritive value.

Unfortunately, although women were involved in post-harvest and household activities they were unwilling to be interviewed by male researchers, and gender issues will need to be addressed in any subsequent work.

Pesticide dealers were considered by farmers to be a main source of knowledge on pest control, although 65% indicated that they chose an insecticide based on brand name. Despite the apparent importance of stem borers, farmers spent only 2–5% of their crop production costs on insecticides – although this was significantly higher than for other pests, apart from weeds. Over 60% of farmers interviewed had received IPM training, and over

*The water trap (used here in brinjal) being tested for effectiveness in the field*

80% believed it was effective, but few practised it. Pesticides were generally considered to be effective and, although most farmers were aware of side effects, over 80% of farmers surveyed used them to control stem borers.

Farmers involved in the trials were unclear about the effectiveness of pheromone traps, in part because of low infestation levels. To test their interest in the technology, farmers were offered a chance to purchase traps. Seven farmers bought 27 traps between them and, on seeing the moths they caught and the low infestation levels in their fields, were generally pleased with the technology. They suggested they would purchase them again and motivate neighbours to use them, but price was an important criterion in their choice of stem borer control technology.

Efforts were made to ascertain the costs to smallholder farmers of rice production and to determine whether mass trapping would be cost-competitive with current insecticide-based control practices. The cost of rice cultivation was typically US$255–288 per ha per season, with insecticide use accounting for 2–5% of these costs. The mass trapping technology requires 20 traps per ha with two lures per trap to cover the period when the crop is at risk from yellow stem borer. The sleeve trap adopted for use in mass trapping was estimated to cost a maximum of US$21 per ha per season, or 7–8% of crop production costs. This suggests that mass trapping is more expensive than currently used levels of insecticide. However, the averaged insecticide cost disguises the fact that some farmers do not apply insecticide at all (approximately 20% of those surveyed), so those who do will actually spend more than the averaged value. In addition, pheromone traps can be used for a number of seasons and farmers are unlikely to adopt the density

*The plastic sleeve trap was more effective at higher levels of catch and was unaffected by the weather*

used in trials. The traps used in the trials are being imported from India, but could easily be made locally when demand develops (see page 171).

Prior to the project, the Government of Bangladesh had no legislation governing the registration and use of biopesticides and related biorational pest control technologies, even though IPM is widely promoted as the method of choice for agricultural pest control. NRI provided technical assistance to Syngenta and BRRI in their efforts to clarify the position with the Pesticide Technical Advisory Committee. Following intensive lobbying by Syngenta, BRRI and the Bangladesh Agricultural Research Institute (BARI), the Committee accepted that pheromones were a special case and has allowed Syngenta to submit documentation for registration of pheromone products, Giant and Gem, for control of brinjal shoot and fruit borers, and fruit fly, respectively.

This activity has resulted in policy change and increased the profile of biopesticides within Bangladesh to the extent that other biopesticides are now actively being considered for pest control, notably nuclear polyhedrosis virus and neem products.

Pheromone trap-catch data suggest that traps can be used to predict the emergence of adult moths and hence the likely timing of mass trapping or other remedial actions to control progeny. Syngenta will promote pheromone traps in the first instance for monitoring and, depending on farmer interest, will introduce mass trapping in selected areas as part of its IPM Farmer Field School Programme (see page 163).

## FURTHER APPLICATION

Syngenta is now committed to implementing the pheromone technology and incorporating it as a component in its Farmer Field School Programme.

Given the technical advances made as a result of the project and the greater understanding of farmers' perceptions, the next step is to move towards actively assisting Syngenta to market pheromones and developing and implementing technical training packages in IPM for pesticide dealers, NGOs and extension workers for both rice and vegetables (see R8367, page 169).

This project has successfully brought together a private-sector organisation and the government-funded rice research institute, and has developed links with the Department of Agricultural Extension. Thus a strong alliance is in place for sustainable implementation of the outputs. By identifying the central role of pesticide dealers in the provision of pest management advice, as well as products, to rice farmers the project has helped to target delivery mechanisms more precisely.

# Promoting farmer adoption and policy change for rice and vegetable pest pheromones in Bangladesh

**R8367**

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Sarwar Ahmed
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April 2004–March 2005

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CORK, A. (2005) Technology and application of semiochemicals in pest control: problems and perspectives. Presented at the International Symposium on Herbal Medicine, Phytopharmaceutials and other Natural Products: Trends and Advances, 15–17 June 2005, Colombo, Sri Lanka.

CORK, A., ALAM, S.N., RAHMAN, M., KAMAL, N.Q. and TALEKAR, N.S. (2004) Mass trapping for control of rice and vegetable pests in South Asia. In: *Proceedings of the XXII International Congress of Entomology*, 15–21 August 2004, Brisbane, Australia (abstract).

CORK, A., ALAM, S.N. and TALEKAR, N.S. (2005) Development and commercialization of mass trapping for control of brinjal borer, *Leucinodes orbonalis* in South Asia. pp. 29–33. In: *Proceedings of National Symposium on Recent Advances in Integrated Management of Brinjal Shoot and Fruit Borer*, 3–4 October 2005. Indian Institute of Vegetable Research, Varanasi, India.

CORK, A., ALAM, S.N., ROUF, F.M.A. and TALEKAR, N.S. (2005) Development of mass trapping technique for control of brinjal shoot and fruit borer, *Leucinodes orbonalis. Bulletin of Entomological Research* 95: 1–8.

The aim of this project was to develop and promote pheromone technologies for control of major crop pests in Bangladesh, including brinjal shoot and fruit borer and rice stem borers. Training and marketing materials were developed for pesticide dealers and for rice and brinjal farmers on the use of pheromone traps and related IPM technologies. The project worked with Syngenta and its dealer network in order to build capacity and facilitate understanding of the nature of pheromones and their potential for pest control, and through lobbying to enable the registration for sale of these affordable and sustainable products.

## ISSUES

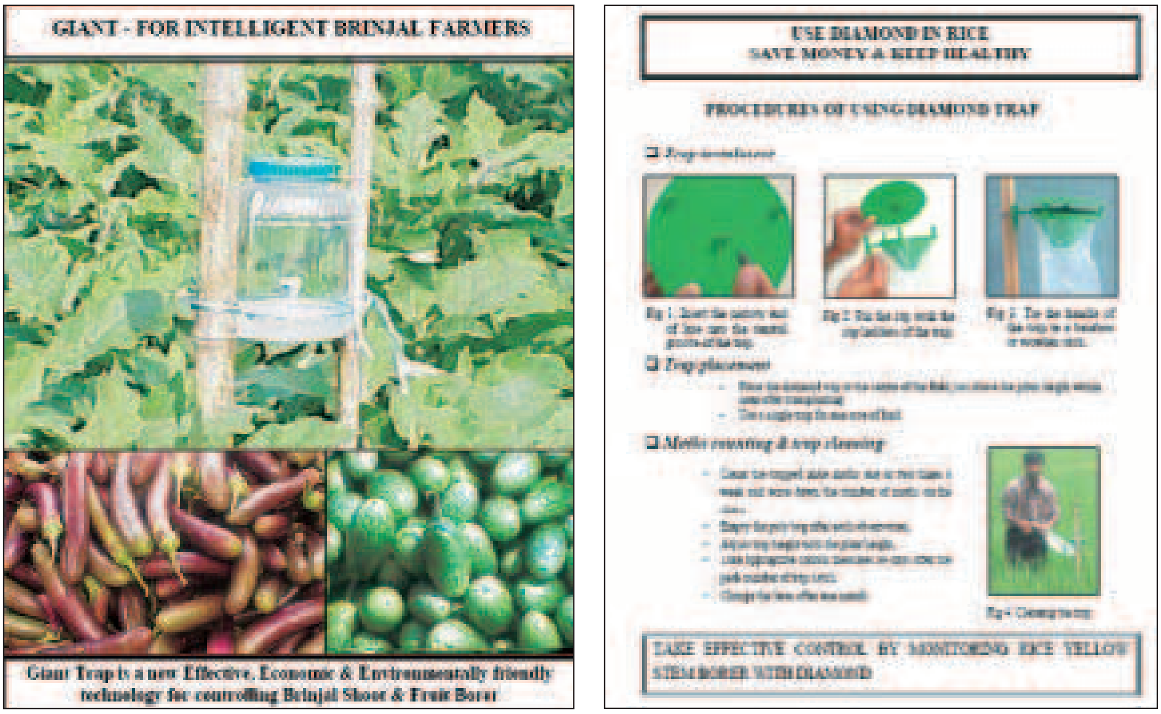
Various CPP projects have produced and refined simple, practical, pheromone-based technologies to help control crop pests and reduce the over-use of high levels of pesticide. These include a pheromone-based mass trapping system for male yellow stem borer (*Scirpophaga incertulas*) in rice (R8026, see page 165), and a related CPP project for control of brinjal shoot and fruit borer (*Leucinodes orbonalis*) in India and Bangladesh (R7465). While these practical technologies are affordable and easy to use, their uptake is limited for a variety of reasons, including limits on local production (R8304, page 171) and the lack of an infrastructure for the registration of relatively new biotechnology products (see page 168). Following intensive lobbying by Syngenta, BRRI and BARI (see page 168), Bangladesh's Pesticide Technical Advisory Committee has for the first time allowed Syngenta to submit documentation for registration of two pheromone products: Giant, for control of brinjal shoot and fruit borer; and Gem, for control of the fruit fly *Bactrocera cucurbitae*.

*Brinjal (eggplant or aubergine)*

## ACHIEVEMENTS

The ultimate aim was to create a platform in Bangladesh to promote pheromone products to a receptive farmer population and to enable sustainable transfer of the technology into the market. A key advantage of this approach was the ability to draw on the considerable influence wielded by pesticide dealers and a major agribusiness company, Syngenta, to promote products to farmers. Syngenta has a reputation for high-quality products in Bangladesh and commands considerable brand loyalty. With a network of 12,000 pesticide dealerships, the prospects for achieving sustainable impact at the farmer level augured well, provided the products were marketed with the correct approach and the price compared well with alternatives. While the potential to provide Syngenta with a significant financial advantage was recognised, it is anticipated that other agrochemical companies will enter the market place in time, ensuring that prices to the farming community are competitive.

Farmers' views of pheromone technology were sought, and strategies were developed for overcoming risk aversion to new technologies among farmers. Farmer demonstration trials and




*Selections from flyers for pheromone-based products available in Bangladesh – Giant trap for brinjal shoot and fruit borer, and Diamond traps for yellow stem borer*

stakeholder meetings to assess their responses to the new products received positive feedback. However, problems with one batch of commercially produced lures highlighted the need for effective quality assurance of products before release to farmers.

Baseline socio-economic data were obtained on farmers and pesticide dealers involved in the control of rice and brinjal pests at three locations in Bangladesh. Pesticide dealers were positive about the new technologies for control of brinjal borer although, in common with farmers, they needed reassurance that the technologies were effective and would provide an acceptable economic return. Dealers indicated they received a 10% profit margin on pesticides.

Farmer surveys provided evidence for the positive impact of farmer training sessions on the use of rice and brinjal pheromone products, although many farmers felt the need for additional technical assistance. Syngenta aims to accommodate this by focusing promotional efforts on particular areas or whole villages.

Syngenta's marketing strategy for rice and brinjal pheromone products has been enhanced by the information gathered, and promotional materials for farmers, pesticide dealers and Syngenta personnel have been published in the form of flyers (printed in Bengali and English), and a multi-media presentation that describes the problems associated with insecticide use, the function of pheromone traps and how they can be incorporated into IPM strategies for rice cultivation.

Of the vegetable-production land in Bangladesh, 19% is used for cultivating brinjal, which represents 41% by weight of the vegetables produced. Replacement of insecticides for control of the major economically damaging insect pest *L. orbonalis* with a benign control technology (Giant), which has a cost–benefit ratio of at least 1 to 1.8, will contribute significantly to reducing the impact of key pests and diseases, improving yields and reducing pesticide hazards.

Legislation to enable biopesticides, including pheromones, to be registered for use in Bangladesh has now been accepted by the Pesticide Technical Advisory Committee, but not yet gazetted into law by the end of the project.

## FURTHER APPLICATION

By late 2005 the registration process had been gazetted into law and negotiations to secure a supply of active compounds in the region are well advanced. Syngenta is now at an advanced stage of developing additional semiochemical-based products to extend the range of production systems affected. It is anticipated that, should the process be successful, Syngenta may well adopt a similar approach in other regions where these or related insect pests are economically important.

Nevertheless, technical gaps remain, such as the need for knowledge on the relationship between rice stem borer damage and pheromone trap catch to enable Syngenta to provide farmers with an action threshold. Data on the proportion of an available adult pest population that can be trapped with current technologies would provide a better insight into how these trapping systems can be optimised further.

# Technical support for SMEs supplying pheromone-based pest control technologies in South Asia

**R8304**

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September 2003–September 2004

Although useful technologies have been developed using pheromones to control a number of key insect pest species in various crops in South Asia, their use is dependent on the availability of quality products at an affordable price – and that is achievable only through local production. This project researched the constraints on small and medium-sized enterprises manufacturing and marketing pheromone products in South Asia, in order to develop and implement strategies for overcoming those constraints.

## ISSUES

Considerable advances have been made in developing IPM-based control strategies for crops in South Asia that incorporate semiochemicals (pheromones) to control key insect pest species. Much of this work has been funded by DFID through the CPP, notably control of the rice yellow stem borer (see R8026, page 165) and the brinjal shoot and fruit borer. Pheromones for coffee white stem borer, groundnut leaf miner, sugarcane borer species and cotton pests have also been identified.

Despite this work, only one pheromone has been registered for use in control in South Asia. There are many reasons for the lack of commercialisation of pheromone-based systems in the region. In India, mating disruption was found to be efficacious for control of yellow stem borer in rice, but was not cost-effective. Nevertheless, the Indian national programme continued the work and developed mass trapping as an efficacious and cost-effective alternative (see page 165). They went further and promoted the technology through extension services, but despite considerable demand from farmers (10,000 lures sold per year) they were unable to sustain this endeavour because of the lack of active compounds. Successful promotion of pheromone-based technologies and their adoption by smallholder farmers is dependent on the availability of high-quality, affordable products, which can only be made available through sustainable local production.

## ACHIEVEMENTS

This project aimed to identify and resolve technical constraints facing small and medium-sized enterprises (SMEs) manufacturing and marketing pheromone products in South Asia. Three activities were undertaken:

- industry survey
- stakeholder workshop
- pheromone manual.

Pheromone-related pest control technologies are exclusively manufactured and marketed by SMEs in South Asia. Despite some natural reticence among SMEs to collaborate in market-oriented activities, the SMEs producing pheromone products were supportive and cooperative. Sixty per cent of the SMEs producing pheromone products in South Asia actively participated in the survey and stakeholder workshop.

Together, the companies produce and market 1.6 million pheromone lures per year for use on 13 economically important insect pests, covering a range of crop types. Nevertheless, cotton pests accounted for 95% of production, with the majority of traps and lures being sold through the State Government procurement system.

The industry survey found that most SMEs were optimistic about the future, with 57% expecting sales to increase and 36% believing

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AHMAD, R. (2004) Goodbye pesticides – pheromone trap working wonders in Jessore. *The Daily Star*, 18 June (India).

CORK, A. (2004) Enabling small and medium enterprises to promote pheromone based pest control technologies in South Asia: Pheromone manual. Natural Resources Institute, Chatham, UK.

CORK, A., JAYANTH, P. K. and NARASIMHAN, S. (eds) (2004) Enabling small and medium enterprises to promote pheromone based pest control technologies in South Asia. Proceedings of UK DFID-funded Project Workshop, Silver Oak Resort, Bangalore, India, 25–26 May 2004. Natural Resources Institute, Chatham, UK.

that sales will stay at similar levels in the near future – broadly in line with the rest of the world, where the market for pheromones is growing at about 10% per year. SMEs felt that pheromone supply was a major constraint, with most pheromone being imported through just one company in a final blended form. Unlike other biopesticides, pheromones are subject to an import tax, but access to ISO9002 certified material enables the smaller producers to compete with larger companies. Most SMEs rely on other product ranges to achieve a financially viable business, typically production and distribution of seeds, viruses and/or natural enemies.

An international stakeholders' workshop was conducted involving 50 participants from four countries. The workshop provided a venue for dissemination of information by invited experts, both national and international. These activities provided the background information for the development of a *Pheromone Manual* that was produced to provide answers to the technical questions raised by SMEs. From the nature of some of the questions raised at the workshop, it was apparent that there was considerable uncertainty among SMEs, and some scientists, about the scope and limitations of the technology. The role of major pheromone products for monitoring pests in India is still poorly defined, and until SMEs and extension agencies can provide farmers with well defined protocols for using the products, they will not be widely adopted on a sustainable basis. Areas where government and SMEs could play a role in the future development and dissemination of these technologies were identified.

**Quantity of pheromone products sold per year by SMEs in South Asia**

| Insect species | Crop attacked | Quantity of lures (x1000) |
|---|---|---|
| *Helicoverpa armigera* | Cotton/other | 830 |
| *Spodoptera litura* | Cotton/other | 480 |
| *Earias vittella* | Cotton | 280 |
| *Pectinophora gossypiella* | Cotton | 130 |
| *Leucinodes orbonalis* | Brinjal (eggplant) | 10 |
| *Scirpophaga incertulas* | Rice | 20 |
| *Plutella xylostella* | Brassicas | <10 |
| *Rhynchophorus ferrugineus* | Palm | <10 |
| *Bactrocera cucurbitae* | Cucurbits | <10 |
| *Bactrocera dorsalis* | Fruit | <10 |
| *Odoiporus longicollis* | Banana | <10 |
| *Homona coffearia* | Coffee | <10 |
| *Spodoptera exigua* | Cotton | <10 |

Workshop participants identified a number of themes that represented the major constraints to the industry: source and cost of pheromone; quality assurance; registration; and markets. Workshop recommendations included:

- a society to represent the industry
- training package for SMEs on product evaluation
- identification and promotion of new market opportunities.

## FURTHER APPLICATION

As many SMEs producing pheromones were found to have a weak understanding of the function and utility of their products, a second phase of the project (R8367, page 169) and extension project R8413 aimed to build capacity through hands-on training for appropriate company personnel in the analysis of pheromones and formulated materials.

# Promotion of integrated weed management for direct-seeded rice on the Gangetic Plains of India

**R8233**

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January 2003–March 2005

Rice–wheat cropping is an effective use of land to maximise yields of vital cereal crops in India. However, the cropping system is facing constraints in part related to combining two crops with different growth habits and requirements. This project built on previous work to promote the adoption of direct-seeded rice, combined with appropriate weed management, to rice–wheat farmers on the Gangetic Plains of India. Field trials demonstrated that yields in direct-seeded rice can be comparable with those in transplanted systems. In the absence of weed control there is a significant reduction in yields under direct seeding, but this can be minimised with appropriate weed-management. The use of a herbicide followed by a single hand-weeding conferred a significant benefit in comparison with hand-weeding alone. The research has shown that changes in composition of the weed flora occurred under different direct-seeded crop establishment – information important to future weed-management strategies. Shortages of labour and water, coupled with the incentive for many farmers to reduce overall input costs, are likely to result in widespread adoption of direct seeding in many parts of the Gangetic Plains. The need to control weeds to protect yields will be paramount, and this project has laid a sound basis for the development and promotion of appropriate weed-management practices.

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MORTIMER, M. and JOHNSON, D. (2004) Common weeds of lowland rice in India. International Rice Research Institute, Los Baños, Philippines (poster).

JOHNSON, D.E., MORTIMER, M., ORR, A. and RICHES, C. (2003) *Weeds, Rice and Poor People in South Asia.* Natural Resources Institute, Chatham, UK. 10 pp.

SINGH, G., SINGH, Y., SINGH, V.P. *et al.* (2003) Direct seeding as an alternative to transplanting rice for the rice–wheat systems of the Indo-Gangetic Plains: sustainability issues related to weed management. pp. 1035–1040. In: *Proceedings of the BCPC International Congress on Crop Science and Technology 2003*, Glasgow, UK. British Crop Protection Council, Alton, UK.

SINGH, Y. (2004) Direct seeding of rice in Indo-Gangetic Plains. Paper presented at Irrigated Rice Research Consortium, International Rice Research Institute (IRRI), Los Baños, 2 December 2004.

## ISSUES

Rice–wheat is the principal cropping system of the Indo-Gangetic Plains, occupying some 13.5 million hectares and contributing 40% of India's grains. Its sustainability is vital to the livelihoods of farmers in the region, and to national food security. Traditionally, rice is transplanted at the end of the dry season (May/June) after the land has been flooded and puddled; wheat is planted in the rabi season (November/December). Constraints include an increasing shortage of agricultural labour; increasing labour costs; the relative cost of fertiliser and fuel; and late sowing of wheat (partly dependent on the date of rice harvest).

Rice is direct seeded either by dry or wet seeding, which relates to the physical condition of the seedbed and seed (pregerminated or dry). Dry drill-seeding of rice can be complementary to reduced or zero-tillage systems for wheat, as the same seed drills can be used. Direct seeding of rice is thought likely to reduce delays in sowing wheat, as it advances the start of the rice season by up to a month, resulting in an earlier harvest. A concern for the sustainability of the rice–wheat

*Farmers in Bihar tend to use less mechanisation than in Uttaranchal* system is the long-term effect of alternate dry and wet cultivations for wheat and transplanted rice, respectively. Wet cultivation (puddling) largely destroys the natural soil structure in the surface layers. While this is good for water management in transplanted rice, it reduces the yield potential of the subsequent wheat crop. Dry direct seeding of rice avoids the need to puddle the soil, so the soil structure is retained with potential long-term yield benefits.

This project built on the development of direct seeding and associated weed-management options initiated under project R7377, which established that yields from direct-seeded rice can be comparable with those from transplanted rice if weed management is adequate. The role of the current project was to demonstrate the opportunities for direct seeding of rice to farmers across a wide geographical area on the Indo-Gangetic Plains.

## ACHIEVEMENTS

On-station experiments in Uttaranchal, Uttar Pradesh and Bihar demonstrated that yields from wet direct-seeded rice are broadly comparable with transplanted rice provided that weed management is effective, while yields of direct-seeded rice tended to be about 0.5–1 t/ha less than from transplanted rice. If weeds were not controlled, yields in direct-seeded rice were a small fraction of those from transplanted rice. Highest yields were always achieved with a single herbicide application and at least one subsequent hand-weeding. These findings were validated in three states over 48 farmers' field trials in 2003 and 67 field trials in 2004.

In 2004, for the fourth successive year, at Pantnagar wet direct-seeded rice gave the greatest yield: 7.1 versus 6.8 t/ha for transplanted and 5.9 t/ha for dry direct-seeded. In Pantnagar District, on over 20 farms, mean yields from transplanted rice were greater than from direct seeding (5.2 versus 4.8 t/ha). However, farm trials indicate that, with extension support, direct-seeded rice can achieve equivalent yields to transplanted rice across a range of rice cultivars in common use.

*Weed identification poster produced and disseminated by the project*

Direct-seeded rice was privately profitable for farmers, giving net returns of Rs13,350 per ha for dry direct-seeded and Rs11,592 per ha for wet direct-seeded rice, compared with Rs10,343 per ha for transplanted rice. Net labour savings with direct-seeded rice compared with transplanting averaged 27 days/ha.

Around Pantnagar, 46% of the cropped area belongs to farms larger than four hectares, and these holdings incur high variable costs for tractors and irrigation pumps in the rice–wheat system. With market liberalisation, spiralling costs are a powerful incentive for adoption of direct-seeded rice, which might not be justified solely in terms of labour costs. The incentives for adoption are likely to vary regionally, however. Direct seeding is usually seen as part of the solution to the 'yield problem' in the rice–wheat system. Larger-scale farmers around Pantnagar see the need to reduce unit costs, and recognise that this is possible by increasing wheat yields and adopting direct-seeded rice. These farmers see real and immediate benefits from direct-seeded rice and zero tillage by reducing cash outlay for mechanised tillage and labour for transplanting. Partial budgets for direct-seeded rice and transplanted rice were produced from data collected from 20 on-farm trials around Pantnagar in 2004. The data indicated that:

- total costs for direct-seeded rice (Rs13,816 per ha) were lower than for transplanted rice (Rs18,256 per ha) by Rs4440 per ha
- puddling (Rs2448 per ha) accounted for 55% of the difference in costs
- yields did not differ significantly, resulting in a higher cost:benefit ratio for direct-seeded rice (1.59) than for transplanted rice (0.96).

The species composition of the accompanying weed flora may also change with management practices. Direct seeding of rice is known to be accompanied by a rapid shift in the weed flora, with an increase in abundance of *Echinochloa crus-galli*, *Echinochloa colona*, *Ischaemum rugosum* and *Leptochloa chinensis* and, on more freely draining soils, *Cyperus rotundus.* The ingression of annual grasses and perennial sedges presents particular weed-management problems with continuous direct seeding. Data sets compiled have facilitated the development of decision frameworks and will underpin the widespread application of weed-management strategies.

Farmer groups in Uttaranchal, Uttar Pradesh and Bihar, who previously transplanted rice, were introduced to options for direct-seeded rice and the related weed-management practices. On-farm trials over several seasons at these sites demonstrated that direct-seeded rice can be successful. Many farmers have expressed considerable interest, and the systems are being adopted among lead farmers.

*Transplanting is labour-intensive, costly and can cause delays*

A total of 13 farmer field days were held, with events at each of the partner sites (GBPUAT, NDUAT and RAU), and were well attended by farmers and state officials. In 2004, at Patna, 700 farmers and a Government Minister attended one meeting and 250 farmers another; at Faizabad 250 farmers; and at Pantnagar 53 farmers and 16 scientists attended other field days. In Uttar Pradesh and Bihar, diffusion of the direct-seeded rice technologies has led to approximately 250 ha of direct-seeded rice being grown by farmers in 2004. Leaflets and posters on the technologies for direct seeding have been published in English and Hindi.

The project has established effective collaboration among three key agricultural universities in India, IRRI, the University of Liverpool and NRI. This enabled a multi-disciplinary team covering socio-economics, weed ecology and agronomy to link effectively with regional organisations, local administrative bodies, extension organisations and farmers' groups, in order to develop effective and appropriate weed-management options. The Chandra Shekhar Azad University of Agriculture and Technology (CSA Kanpur) joined the activities on direct-seeding technology with independent funding, and is keen to expand activities.

The prospects for adoption of direct-seeded rice in eastern India are brighter than previously thought, based on an analysis of existing crop-management practices for transplanted rice and farmer evaluations of on-farm trials. The results show no difference in average time of transplanting by farm size, suggesting that small as well as large farms would benefit from more timely crop establishment.

Livelihood diversification through seasonal migration has increased incentives for adoption of labour-saving technology, particularly in the light of the 'feminisation' of agriculture, where female family members substitute for men. Direct-seeded rice reduces the climatic risk caused by unpredictable monsoon rains. Reducing dependence on pump sets and tractors for timely crop establishment will benefit poorer farmers. Participatory evaluation shows that savings in labour costs were less important for large-scale farmers than savings in the costs of tillage and irrigation.

## FURTHER APPLICATION

A follow-on promotional project with the main Indian partners (GBPUAT, RAU, NDUAT and CSA) will continue until January 2006 (R8409). This will address some of the information gaps identified during the research, and develop decision tools for improved weed management. There are additional researchable issues that could usefully be pursued in a future research programme: for example, management of weeds as species shifts occur; and issues concerning weedy rice and insecticide resistance.

The technology options for direct-seeded rice and the associated weed-management practices will be evaluated and promoted elsewhere in South Asia under the Irrigated Rice Research Consortium (IRRC) and the Consortium for Unfavorable Rice Environments (CURE) of IRRI.

# Promotion of cost-effective weed-management practices for lowland rice in Bangladesh

**R8234**

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January 2003–March 2005

Closing the gap between the rice yields achieved by the best farmers and those with only average yields has now become a high priority in Bangladesh, and will largely depend on improvements in farmers' management practices. This project demonstrated that improved weed-management practices can reduce input costs and enhance productivity in intensive transplanted rice–rice systems in Comilla District, Bangladesh. Importantly, the use of herbicides can produce benefits in the Aman as well as the Boro season. The technology is knowledge-intensive, and the project developed innovative ways to work with the private sector and other organisations to disseminate relevant information more widely. Significant yield gains have also been shown in rice/rabi crop systems in the Barind Tract, through on-station and on-farm trials. A key feature of the work in this area is the focus on increasing overall system productivity. The use of direct seeding increases the opportunity for farmers to plant a rabi crop on residual moisture. Sustainable intensification of under-utilised agricultural production areas, such as those in the Barind Tract, is needed to increase national rice production and facilitate diversification into other crops. There is good potential for expanding production of rabi crops in this region. The crop-management systems promoted have good potential to ameliorate some of the key constraints to rice production in Bangladesh.

## ISSUES

To keep pace with internal demand in Bangladesh, it has been estimated that paddy production will need to increase from the current level of 22 million to 50 million tonnes by 2020, an annual growth in yield of 1.5–2%. Widespread adoption of fertiliser-responsive modern varieties and expansion of the area under irrigation have driven the increase in rice production over the past 20 years in Bangladesh. In Comilla District, for example, which has long been at the forefront of adoption of modern rice-production practices, 80 and 100% of Aman and Boro crops, respectively (see Glossary, page vii), were planted to modern varieties by 1999. Future increases in rice production will therefore also depend on improvements in the efficiency with

*Hand-weeding in Bangladesh*

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*Poster on 'Effective control of weeds in rice' displayed in pesticide stores in Paruara Bazaar, Comilla District*

which inputs are used. Closing the gap between the rice yields achieved by the best farmers and those with only average yields has now become a high priority. Reducing this yield gap will largely depend on improvements in farmers' management practices. Characterisation work by the earlier project R7471 and needs assessments undertaken independently by the Dhaka based DFID-funded Poverty Elimination Through Rice Research Assistance (PETRRA) Project have confirmed that weed control is a major cost to farmers in the rice-production cycle in Bangladesh.

The High Barind Tract includes 12% of the drought-prone rainfed lowland rice grown in Bangladesh. Drought early in the season causes delays in transplanting, while an early cessation of the rains in October impacts on grain filling resulting in low yields. Due to the limited irrigation potential of the area, there is relatively little production of Boro (irrigated) rice in the dry rabi season. Thus much of the land lies fallow during the rabi season. Work undertaken by BRRI over the past 12 years has led to the development and testing of a system that can allow farmers to increase cropping intensity by more reliable establishment of a rabi chickpea crop. This can be achieved by direct seeding a short-duration rice variety to reduce crop duration to 125–130 days, thereby releasing land when there is still sufficient moisture for rabi crop establishment. However, weeds are a major constraint to adoption as the advantage of effective weed control prior to transplanting through puddling is lost when rice is established by direct seeding.

There are therefore two situations in which the promotion of improved weed control can contribute to increased rice productivity in the Barind – in the existing transplanted T-Aman, and in rice established by direct seeding.

Results from the previous project (R7471) provided a platform from which to scale up validation and promotion of weed-management options. This new work was designed to address the challenge of how to close the yield gap between the best on-farm yields and those of the majority of growers, through the promotion of a range of sustainable weed-management options.

## ACHIEVEMENTS

On-farm trials at 20 sites over two years have shown herbicide use to be a robust, effective and profitable technology under various water-management scenarios in both Aman and Boro rice in Comilla. Herbicide use was demonstrated in transplanted rice in collaboration with the Department of Agricultural Extension (DAE) at 60 sites per season in four *upazillas* (local government areas) in Comilla District, south-eastern Bangladesh. Training of extension officers in the safe, efficient use of herbicides prior to each season, and farmer field days, were undertaken as components of the demonstration programme. Rice herbicide promotion by the private sector led to 43% increase in sales between 2002 and 2003.

Both farmers and extension workers need information about safe and profitable herbicide use, and on the integration of herbicides with cultural practices. In collaboration with the NGO SAFE, a partnership was developed between the NGO and the herbicide manufacturer Syngenta, resulting in a training manual on herbicide use that has been distributed to all *upazilla* agricultural offices in Bangladesh. The project also raised awareness of information issues in the private sector through a seminar and discussions with nine companies marketing herbicides. A poster covering key issues on safe and efficient use of herbicides was prepared and distributed for display in pesticide dealers' stores throughout Comilla District, making use of the Syngenta dealer network.

*Field-scale evaluation of direct seeding by farmer group in Godagari* upazilla*: transplanted rice variety Swarna surrounding maturing crop of BR31 direct-seeded with a hand-pulled furrow-opener (*lithao*)*

The challenge in the drought-prone, rainfed agriculture of the Barind Tract is simultaneously to improve the reliability and yield of Aman rice, and to increase the area planted to drought-tolerant post-rice crops. Research trials at 25 sites and field-scale evaluation by farmers at 30 sites demonstrated that dry direct seeding or wet seeding of pre-germinated seed reduces the labour requirement for crop establishment, resulting in rice yields similar to, or higher than, conventional transplanting. This system also advances harvest by a week to 10 days. Harvesting earlier reduces the risk of terminal drought in rice when the monsoon ends abruptly, and increases the opportunity for establishing a post-rice crop of chickpea on residual moisture.

Field work demonstrated that herbicide use is essential to facilitate direct seeding, and this further reduces rice-production costs. Herbicide use, to overcome late weeding due to labour constraints in transplanted rice, was demonstrated by DAE and the NGO People's Resources Oriented Voluntary Association (PROVA) at 100 sites across three districts in the Barind Tract, in collaboration with a DFID Plant Sciences Research Programme-funded project working on rabi crops. Herbicide use and the modified rice/rabi system using direct seeding are knowledge-intensive. A shift in weed species abundance was observed following the long-term use of direct seeding, and control needs to be factored into farmer training. Widespread sustained adoption will depend on farmers undertaking timely tillage, adequate land levelling and timely application of herbicides.

In collaboration with NGOs and the DAE, research partners have developed and promoted a range of sustainable weed-management options for rice. This has improved understanding of the agronomic, technical and socio-economic opportunities for productivity gains in two widespread rice-based systems in Bangladesh. Improved weed management will benefit poor rice farmers and sharecroppers directly by reducing unit costs for rice production and, in the Barind Tract, enhancing land productivity and income from rabi cropping. By helping to maintain rice productivity growth and lower rice prices, improved weed management will also benefit poor consumers. The social costs of labour displacement from herbicides and direct-seeded rice will be reduced by the rapid growth of non-farm rural employment (e.g. in construction, brick fields etc.). Adoption of labour-saving technology in rice reflects growing livelihood diversification and the diminishing importance of agricultural labour among the rural poor.

## FURTHER APPLICATION

Access to knowledge is the key for farmers to take advantage of new rice-management opportunities. An extension to this project (R8412) will consolidate knowledge and make it accessible in a form that enhances understanding of the new technology, promotion by extension, and adoption by farmers. This will be achieved by developing a decision-support framework that will distil research findings into an interlinked set of decision tools for improved weed management of transplanted and direct-seeded rice, and for transition between both. There is scope for synergy between these activities and project R8233 (page 173) on direct-seeded rice in India.

To strengthen the knowledge base for decision-support frameworks in rice/rabi, trials will evaluate different methods of direct seeding on a field scale to gain more experience in field-scale mechanisation. This will broaden understanding of the options available to farmers. The IRRI Rice Knowledge Bank is being developed to provide a web-based resource on rice production, and will be the major route for dissemination of information through a recently initiated programme of rice-technology promotion funded by the EU. Outputs will be prepared in a format suitable for inclusion in the Rice Knowledge Bank to ensure they remain available for use beyond the end of the CPP project.

# Ecologically based rodent management for rice-based cropping systems in Bangladesh

**R8184**

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April 2002–March 2005

This research project addressed the many impacts of rodents on rural agricultural communities in Bangladesh, and aimed to develop sustainable methods of managing them. Rodents have a significant effect on people's livelihoods in many ways, causing damage to rice and other crops; loss and contamination of stored rice; damage to buildings; contamination of food and water supplies; and damage to personal possessions, such as clothes, fishing nets and furniture. Commonly recommended approaches to managing rodents using rodenticides are often inappropriate for rural communities, and have the potential to cause damage to human health and the environment. Various appropriate rodent management methods were evaluated in villages, and significant reductions in rodent numbers were achieved through community-wide intensive trapping of rats with snap traps. A number of environmental management options were demonstrated that could lead to permanent reductions in rodent populations – if they are adopted by a significant proportion of households. The findings were discussed with key stakeholders including the Department of Agricultural Extension, and should help to reformulate existing national strategies and policies aimed at rodent pest management and research in Bangladesh.

## ISSUES

Rodent pests are a serious constraint not only to agricultural production of many crops, but also to the health of people and livestock through the spread of communicable diseases. Rodents are a problem for both rich and poor, individuals and communities, with disproportionately larger impacts on the rural and urban poor, who are least likely to possess the tools and knowledge to control them effectively. Almost any agricultural crop can be attacked by rodents, and they are known carriers of more than 60 life-threatening diseases, including plague and leptospirosis. The numbers of rodent pests are increasing worldwide, and this is likely to continue with urbanisation and agricultural intensification.

In Bangladesh, although effective rodent control methods exist, their poor application and adaptation often results in treatment failures, leading to apathy and widespread acceptance of rodent pests in the environment. Without a good holistic understanding of rodent pest problems and the cost–benefits of rodent control, it can be difficult to convince people that control is achievable and leads to real benefits.

Current rodent control practices are often based on the use of rodenticides. Misuse of these poisons is unfortunately common in many countries, including

Bandicota benegalensis, *the common rice field rat of South Asia (left); stored rice contaminated with rodent faeces (right)*

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*Rats are cooked and eaten in many Asian and African countries*

Bangladesh, posing a threat to human health, and also causing environmental contamination and killing non-target species such as predatory birds. Used correctly, rodenticides can be a highly effective tool. However, they are most appropriate in large-scale, intensive, high-value situations where safety and accuracy can be assured. Other rodent management methods, involving trapping and environmental management, are more appropriate for rural agricultural situations.

This project, to review the multiple impacts of rodents on rural communities in Bangladesh, and to develop and promote sustainable management methods to rural communities and policy-makers, was funded by DFID through the CPP and the Poverty Elimination through Rice Research Assistance (PETRRA) Project.

## ACHIEVEMENTS

The project was based in the districts of Comilla and Feni, south-east of Dhaka. Research activities included an information-gathering phase to improve understanding of the major ecological and anthropogenic issues, and an experimental phase to test new rodent-management strategies.

Villagers clearly identified problems with rodents damaging rice in the field. Farmers were not able to quantify the amount of damage precisely, but they recognised that rodents caused damage at different growing times (e.g. seed beds, maximum tillering, before harvest), and that damage was more severe during different seasonal crops (highest in the T-Aman crop). Farmers also suggested that damage variation between years was high, and that certain areas were more prone to rodent damage. Research trials on damage phenology, which tracked the pattern of rodent damage, showed that damage was patchy and usually highest in areas of fields adjacent to upland areas (dikes, roads, the village, vegetable-growing areas). Rodent damage was strongly correlated with rodent burrowing activity, particularly in the field floor. Active burrow counting could therefore be used as a measure to predict the potential severity of rodent damage, and indices were developed.

Farmers also recognised that rodents attacked a number of field crops in addition to rice. Stored food, particularly rice, was prone to loss, damage and contamination by rodents. Farmers' estimates of rice lost to rodents during storage ranged from 5 to 40%. Trials were developed to measure the impact of rodents on stored rice. Losses over a three-month period per household grain store were typically 35 kg; losses over a year would be enough to provide an additional person's dietary intake per household. A further 2.5% of rice was partially eaten by rodents, significantly affecting its nutritional value, and contamination with rodent faeces could be as high as 300 droppings per kg.

Rodents commonly lived in people's houses, burrowing into floors and walls and living in roof voids. Damage to foundations regularly undermined structures, causing houses to collapse during floods. Rodent damage was also commonly reported to granary structures, furniture, utensils, clothing, fishing nets, electrical wires and other personal possessions.

Rural households did recognise that rodents spread dirt in the environment, and that rodents are unclean. However, general awareness about rodent-transmitted diseases was very low among the majority of villagers. Anthropological assessments of hygiene and food preparation methods indicated that rodents have very easy access to prepared foods and drinking water. Controlled trials indicated high contamination levels of commodities and frequent ingestion of cooked rice by shrews (*Suncus murinus*) caught in villages.

*Livestock fodder haystacks raised above the ground to reduce the number of rats living in them – a further benefit is shelter for poultry and goats*


*Community trap-barrier systems attract rodents from large distances to an early ripening rice crop inside a fence, where they are caught in traps (left). Linear trap-barrier systems stop rodents migrating (right) (photos: Ken Aplin)*

Farmers did use traps and anticoagulant poisons to control rodents. Rodent control was almost always done by individuals, with no efforts to coordinate with neighbours. It was generally accepted by farmers that any benefits of their control activities were temporary. Control was almost always carried out when damage levels and rodent populations were high, and over a short period. Farmers generally planted one row of rice for rodents to every 10 rows planted for themselves as a means of coping with rodent losses.

Trials to monitor rodent population dynamics and breeding rates in a number of distinct habitats (rice fields, houses, vegetable plots, ponds, roadsides) showed no discernible effect of existing control strategies on reducing the rodent population or damage levels. Rodent breeding was correlated with seasonal food availability, and the only population reduction was attributed to widespread flooding in the monsoon season. This indicated that existing practices were largely a waste of time and money.

Intensive village-wide trapping trials with snap traps, and a loan system for live traps, were initiated in two villages. Significant changes were observed with regard to rodent breeding and population dynamics. Compared with two villages without interventions, intensive trapping reduced the rodent population by 75%. Independent monitoring with tracking tiles confirmed that rodent activity had been reduced by approximately 50% through trapping. Post-harvest losses were reduced by more than 60%, with even greater reductions in contamination levels of stored food.

Trials with farmer diaries provided further information on the financial and time costs spent on various rodent-related activities (repairing houses, irrigation canals, rice field bunds and granaries; rodenticide usage; cleaning houses, etc). Intensive community trapping saved time and money compared with the non-intervention villages. Trials were initiated to demonstrate aspects of the environment that could be modified to reduce rodents' access. These included simple measures such as improving hygiene standards, proofing fruit trees (particularly coconut), and modifying granaries and haystacks to reduce rodent access. Monitoring trials indicated desirable effects, and modifications were being adopted independently by other village members.

A workshop was held with invited participants from a number of NGOs and the Department of Agricultural Extension (DAE) to disseminate findings and discuss how activities could be more widely adopted. The DAE-sponsored IPM farmer groups throughout the country are an important organisational structure for the dissemination of agricultural knowledge. Regional roadshows coordinated by the International Rice Research Institute served as a platform to disseminate the project findings, as has the BRRI Rice Knowledge Bank. It was concluded that the DAE's existing national strategy for rodent control (tail collection during a single month of the year when rodent populations are highest) should be abolished, not only because it is ineffective, but also because tail collection would encourage the use of acute poisons as opposed to anticoagulants.

## FURTHER APPLICATION

The research results are being adapted during an extension to the project (R8424) to determine their robustness for more widespread uptake by institutions and rural agricultural communities. A training and dissemination model has been developed to reach new villages and involve staff from NGOs and the DAE, which is now actively engaged in adopting the project outputs.

# IPM of major insect pests of potatoes in the Cochabamba region of Bolivia

**R8044**

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September 2001–August 2004

Andean potato is the principal staple food for Bolivians, providing 30–50% of the total calories consumed by rural highland households. It is grown nationally by around 400,000 small-farm families. For many farmers, potatoes are not only their food staple but also their principal cash crop. Among major problems limiting yields are Andean potato weevils (estimated annual losses US$240–460 per ha) and potato tuber moths (estimated annual losses US$300–500 per ha). Current control practices depend on highly toxic pesticides applied with little or no protective equipment, with substantial adverse impacts on health and the environment. This project aimed to improve approaches to controlling potato tuber moth using entomopathogenic viruses, and to develop traps for Andean potato weevils based on pheromones and other semiochemicals.

## ISSUES

Potatoes are commonly grown in hillside production systems where yields are low due to a complex of factors including weeds, nematodes, pests and diseases, as well as poor soils and erosion. Within this complex, potato insect pests have a major impact on farmers' livelihoods. The two most important insect pests are the Andean potato weevils (*Premnotrypes* spp. and *Rhigopsidius piercei*), no longer limited to the south of Bolivia, and the potato tuber moths *Phthorimaea operculella* and *Symmetrischema tangolias*. Farmers attempt to control Andean potato weevil using two or three applications of toxic pesticides, but spraying is often untimely and dosages are inappropriate so that control is not very effective. In the case of potato tuber moth, some farmers dust potatoes in store with phosphorates, which can be effective for control but poses a great risk to health.

PROINPA, in partnership with CIP and other collaborators, previously developed and commercialised the granulosis virus product 'Matapol' for control of *P. operculella*. This shows efficient control higher than 90%, allowing farmers to save 50% of the cost of seed protection. However, the current powder formulation of 'Matapol' is only suitable for treating small quantities of tubers, and there is a perceived need to develop a new liquid emulsifiable concentrate formulation. 'Matapol' is not effective against the more aggressive potato tuber moth *S. tangolias*, which has now spread to all the main potato-growing areas.

## ACHIEVEMENTS

A new liquid formulation of the *P. operculella* granulosis virus was developed at NRI and evaluated

*As women and children are often responsible for potato growing in Cochabamba, the project targeted schools*

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CALDERÓN, R., OLIVERA, J. and CRESPO, L. (2004) *Guía del Maestro-Segundo Ciclo (5 y 6 Grado) –Educación Para el Medio Ambiente.* Fundación PROINPA, Cochabamba, Bolivia (in Spanish).

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CRESPO, L., HALL, D. and DOWNHAM, M. (2004) Búsqueda de atractantes para el Gorgojo de los Andes. In: *Tercer Congreso de la Asociación Boliviana de Protección Vegetal*, 21–23 Septiembre 2004, Santa Cruz, Bolivia. Fundación PROINPA, Cochabamba, Bolivia (in Spanish) (abstract).

*Farmers examining and assessing the potato crop, Cochabamba (photo: Andre Devaux)*

at various rates in storage situations in Bolivia. High levels of pest infestation were achieved, but there was little reduction in damage to the crop, probably because the virus is too slow-acting. The effectiveness of the 'Matapol' formulation was shown to be due, at least in part, to its kaolin base. There are possibilities for improving this formulation further with a faster-acting strain of the virus.

PROINPA assisted scientists from NRI and CIP in collecting *S. tangolias* to search for a pathogenic virus that could be used for control of this species, as has been done for *P. operculella*. Over 3000 samples of potentially infected larvae were collected and these are still being processed at CIP, although to date no virus specific for *S. tangolias* has been found.

PROINPA, NRI and CIP carried out work on identifying attractants for the Andean potato weevil species *P. latithorax*, *P. suturicallus* and *R. piercei*. Laboratory bioassays and field trapping systems were developed to evaluate natural and synthetic attractants. No evidence was found for intraspecific pheromonal communication in any of the species. However, weevils were strongly attracted to volatiles extracted from potato leaves. The 44 main components in the collection of volatiles were identified, and two were found to elicit responses from weevils. Dispensing systems were developed and evaluated in laboratory and field bioassays. In the laboratory the synthetic compounds tended to be repellent, probably because the dose was too high, but in the field they were as attractive as potato leaves.

The project also carried out a baseline survey of farmers' perceptions of pests and diseases of potatoes in three communities. Results showed that Andean potato weevil and potato tuber moths were perceived as the most important potato pests. IPM training days were carried out in these communities. Courses were conducted largely in quechua and were attended by men, women and children. Work was also started on educating children in rural schools in IPM of potato pests, using specially designed textbooks. Children and women are often responsible for potato cultivation, and schools provide an untapped opportunity for introducing large numbers of children to the concepts of IPM at an early age.

## FURTHER APPLICATION

For tuber moths, a further project (R8443) has continued to improve the formulation of *P. operculella* granulosis virus, and to process the large number of *S. tangolias* larvae collected, in an attempt to identify a potential virus for control of this species. Despite the initial setback of not finding pheromones for the weevils, considerable progress has been made in identifying attractive components of the host plants, and work is now needed to optimise the attractiveness of traps and to explore their use with farmers. A future goal is to set up a commercial pilot facility for the production of traps and lures based on host-plant volatile attractants.

# Strengthening technical innovation systems in potato-based agriculture in Bolivia (INNOVA)

**R8182**

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April 2002–March 2005

The INNOVA project has its origin in earlier DFID agricultural research and development in Bolivia. One of the main achievements has been to develop, with groups of farmers, an integrated set of mechanisms to link technology demand and supply, and to evaluate potential new techniques. These methods include: informal surveys (*sondeos*) to assess farmers' technology demands; technology fairs for evaluating potential new technologies; local feedback meetings, and municipal evaluation committees. Participatory methods were developed to involve farmers in the evaluation of technological innovation projects supported by the Bolivian competitive funding system. Research outputs that were validated and promoted included: animal traction tillage implements; new forage crops; methods of improving soil conservation; and weed, pest and disease management in different potato-growing systems. The project also focused on institutional mechanisms to link demand with supply in potato-marketing chains. Project innovations include quality standards for *chunio* (dehydrated potato); native, coloured potato crisps; and fresh native potatoes selected and bagged for supermarkets.

## ISSUES

INNOVA builds on agricultural research carried out in Bolivia in the 1990s with support from DFID. A review of activities in Bolivia in 2000 concluded that an integrated crop management project should be developed to bring together and disseminate results of research already carried out in potato-based farming systems, to enhance the impact of this research for poor farmers. As a result of the 2000 review, DFID invited Papa Andina, a CIP-hosted regional programme that promotes strategic alliances for agricultural innovation in Bolivia, Ecuador and Peru, to organise a project planning workshop in June 2001.

There was strong support from DFID's Bolivian research partners for developing an integrated project to address various problems affecting smallholders in the mid-Andean valleys. Such problems include pests (e.g. R8044, page 182), diseases and weeds; soil erosion and declining soil fertility; lack of fodder; and labour shortages. Several possible lines of action were identified. It was believed that inadequate dissemination and uptake of research results were key weaknesses of some past research. To concentrate efforts and for maximum impact, the participating organisations should operate together in a few farming communities, in partnership with municipalities and farmers.

The INNOVA project's main objectives were therefore to expand and improve the use of

*Consistent use of distinctive colours, name and logo (left) helped make INNOVA easily identifiable by information users; logo for native potatoes (right)*

## SELECTED PUBLICATIONS

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PAPA ANDINA/INNOVA (2004) *Articulando demanda y oferta tecnológica. La Experiencia del Proyecto INNOVA – Bolivia*. Memoria del Taller de Evaluación Horizontal, Cochabamba, Bolivia. CIP, Lima, Peru. Fundacion PROINPA, Cochabamba, Bolivia.

PROINPA (2005):
*Producción de forrajes asociados*
*Aporque mejorado con equipos de tracción animal*
*Gorgojo de los Andes: Cómo vive y crece*
*Cómo controlar el Gorgojo de los Andes*
*Calidad de Papa para Chips*
*Producción de semilla de papa de calidad* (technical posters and leaflets). Fundacion PROINPA, Cochabamba, Bolivia.

Website: www.proinpa.org

*Women of the technology evaluation group in Pomposillo, La Paz (Altiplano), showing potato varieties under evaluation (photo: André Devaux, finalist in 'Positive Developments: a photographic exhibition by NR International in association with The Eden Project')*

research information generated with support from DFID; to validate and promote existing technologies; to improve mechanisms to link technology supply with the needs of small-scale farmers; and to develop mechanisms linking farmers to markets. A consortium of three research organisations – the PROINPA Foundation, CIAT (Santa Cruz) and UMSS – was formed to implement the project in three agro-ecological zones: the low valleys of Santa Cruz, the high valleys of Cochabamba, and the Central Altiplano of La Paz.


*All previous project results are available on CD*

## ACHIEVEMENTS

The relevance of existing and new information generated by DFID projects was promoted to national and regional researchers, development institutions, policy-makers, donors and other potential users. A database was created for the storage and distribution of information generated by Bolivian research partners, and made available on CD-ROM and via an INNOVA website (www.proinpa.org/innova/index.htm). INNOVA's communication strategy was to focus on three target groups, and determine their needs for information, dissemination channels, formats and frequency of use. INNOVA has created a distinctive project trademark, used consistently in every information product produced by the project. Visibility and positioning of the INNOVA-developed products have been achieved, and different target groups, especially the Ministry of Agriculture and El Sistema Boliviano de Tecnologia Agropecuaria (SIBTA)'s service providers, are keen to give INNOVA's products a try. Partners' information management and production capabilities have been strengthened.

To identify small-scale farmers' technology needs, an integrated set of mechanisms was established to link supply and demand, including:

- informal surveys or 'demand *sondeos*' to assess farmers' technology needs
- technology fairs to gauge farmers' responses to new technologies
- retro-information, or local feedback meetings
- municipal 'committees with teeth'
- methods developed jointly with the Fomentando Cambios (Promoting Changes, FOCAM) Project to involve farmers in preparing, adjusting and evaluating technological innovation projects in SIBTA and ensure relevance to the poorest farmers.

| Technology | How it changed | Methods that helped |
|---|---|---|
| 1. Improved fallow | Plough the soil, plant in good soil and with oats instead of *Festuca*. Irrigate and fertilise | Technology fair, GET, feedback |
| 2. Grains-plus-legumes | Farmers like to produce vetch seed, which some have been able to do in the higher, colder areas of Cochabamba | GET, feedback, technology fair, MIPITA |
| 3. New fodders | Included with technologies 1, 2 and 4 | Technology fair, GET, CIAL, MIPITA |
| 4 Phalaris grass | Planted in whole fields on the Altiplano. People in the valleys are still adopting it | Feedback, GET, technology fair |
| 5. Chicken manure for nematode control | Place the manure in the bottom of the furrow instead of broadcasting it, to keep it out of one's eyes | CIAL |
| 6. Potato IPM | Soap and detergent to control insect vectors. Fungicides and insecticides are still under study. Control of moths in stores created from scratch | GET, CIAL, MIPITA, technology fair |
| 7. Herbicide for purple nut sedge | Abandoned | Technology fair |
| 8. Improved tillage | Invented high tillage, and a new plough to do it with | Technology fair GET, MIPITA, CIAL |
| 9. Adoption of implements | Extended implements, but also invented the multiple mountain plough | Back-and-forth, GET, CIAL, technology fair, MIPITA |
| 10. Home remedies for cows | Abandoned | Technology fair, short courses in communities |

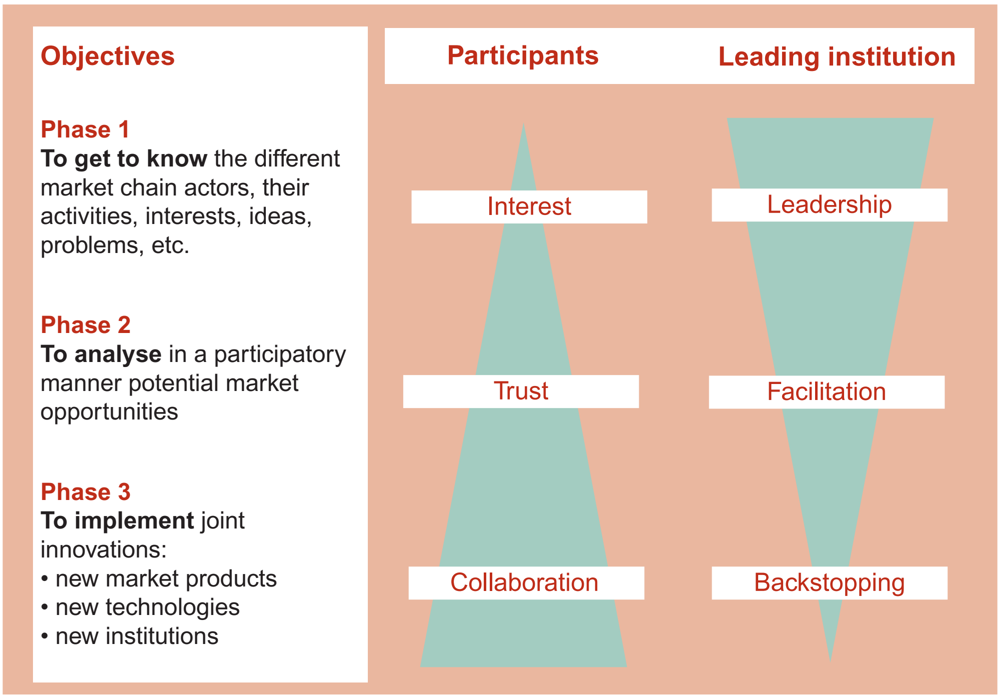
GET: Grupo Evaluador de Tecnología (Technology Evaluating Group); CIAL: Comité de Investigación Agrícola Local (Local Agricultural Research Committee); MIPITA: Modelo Innova de Proyecto de Innovación Tecnológica Agrícola (Innova model of: Agricultural Technological Innovation Project).

*Don Raúl engages the audience at a technology fair*

A second aim of the project was to validate technologies developed through research previously supported by DFID. The project team evaluated about 30 technologies, and farmers have shown considerable interest in several of them.

Animal-drawn tillage implements, including reversible and multiple-use ploughs, were adapted with farmers for potato-growing systems on the Altiplano, and adoption and sales of animal tillage implements in the valleys were enhanced.

New forage crops were validated and promoted to increase the productivity of draught animals, conserve soil, and manage weeds and pests in the potato-growing systems of the highlands.




*Objectives and phases of the participatory market chain approach*

An integrated strategy to manage potato diseases was validated, promoted and used by farmers in the low valleys in Bolivia, to improve productivity and tuber quality.

INNOVA also sponsored innovative studies of competitiveness in the national potato market chain, broadening the concept of demand-led research to include the needs of others (in addition to farmers) in the market chain. Participatory studies identified opportunities for adding value in potato chains in three regions. INNOVA's three case studies helped adapt the participatory market-chain approach (see diagram above), generating innovations in four market segments:

- quality norms established for *chuño* and for *tunta* products (dehydrated potato traditionally processed)
- a stakeholder platform formed for the development of *chuño/tunta* products for which there is public demand
- native, coloured potato chips developed
- fresh native potatoes bagged for supermarkets.

Another important achievement of the project was bringing together three research and development organisations. In the past these organisations all promoted technical innovation in potato-based farming systems, but worked in relative isolation. Helping professionals from different institutions to work in the same locations on a common research agenda has improved their efficiency, allowing them to share their ideas and talents to link technology supply and demand on behalf of poor farmers.


*Innovative products include Lucana: naturally coloured native potato chips*

## FUTURE APPLICATION

Coordination is ongoing with other initiatives in Bolivia [DFID's Fortaleciendo la Innovación Institucional (Strenghtening Institutional Innovation, FIT) Programme and the FOCAM project] and at Andean regional level (Papa Andina/CIP) to promote INNOVA's outputs in a broader context with other partners.

While INNOVA was conceived to fit the Bolivian context, valuable lessons and outputs could be applied elsewhere. For example, a new project of DFID's Crop Post-Harvest Research Programme and implemented with CIP will synthesise and share proven research outputs on the market-chain approach with R&D institutions in Uganda.

CIP and CIAT are currently developing a new project, which will build on the best of INNOVA, FOCAM and the FIT Programme to strengthen capacity in SIBTA and promote the sharing of lessons learned, both across Latin America and with East Africa. Papa Andina is also looking for additional funding from other donors.

# Evolution within *Bemisia tabaci* and associated begomoviruses: a strategic modelling approach

**R8222**

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October 2002–March 2005

The whitefly *Bemisia tabaci*, and the begomoviruses of which it is a vector, can evolve into newly adapted types on a timescale relevant to agriculture, severely hampering the development of sustainable agriculture. This modelling project aimed to identify the potential consequences of pest- and disease-management measures on evolution in *B. tabaci* and in begomoviruses. This work has shown that it is possible to distinguish components of crop resistance that put selection pressure on the virus to evolve more harmful strains. With further studies, it should be possible to develop methods for selecting resistant cultivars, and to select crop- and disease-management methods that do not provoke the virus to evolve into more harmful variants. The evolutionary dynamics of the whitefly *B. tabaci* caused by crop and pest management depends, to a large extent, on its life-history parameters that undergo evolutionary change. Research into evolving life-history traits in *B. tabaci* should be a key area for future research. Preliminary work was caried out on the links between the molecular genetics of begomoviruses and the epidemiology of the diseases they cause. This modelling study has produced information central to further development of disease-management strategies that will not provoke the virus to evolve into more harmful types.

## ISSUES

*Bemisia tabaci* – the main whitefly pest species in the tropics – severely reduces yields by direct damage through feeding, and indirectly through the transmission of viruses. For example, yield losses of cassava in Africa have been estimated at 15–24% of total production, which amounts to an annual loss of US$1.3–2.3 billion. Annual cotton losses in Pakistan were estimated at US$1 billion between 1992 and 1997. Comparable losses have been reported for sweet potato, tomato, cucumber, melon and beans. In the past two decades, worldwide upsurges in *B. tabaci* populations have resulted in an increase in a range of tropical and subtropical whitefly-transmitted diseases. The *B. tabaci*-transmitted begomoviruses have become recognised as emergent pathogens in a range of agro-ecosystems worldwide.

*Bemisia tabaci* adapts readily to new host plants and regions. Evidence suggests that *B. tabaci* is a highly dynamic species complex that is presently undergoing evolutionary change. Little is known about the effect of control measures on evolution within the species complex. Any *B. tabaci* control measure will exert selection pressure on the species complex, and may induce evolutionary change. Sustainable production systems can be developed only via control strategies that do not provoke the evolution of more damaging (bio)types. In the light of growing awareness of the highly dynamic nature of the species complex, strategic insight is needed into its evolutionary change and the resulting consequences for whitefly dynamics, whitefly-transmitted virus epidemiology, and sustainable disease management.

The begomovirus grouping is also a dynamic species complex, from which 'new' viruses emerge. Dramatic examples of the emergence of new virus types are the recent epidemics of cassava mosaic disease in West Africa, and cotton leaf curl in Pakistan and India. Evidence suggests that the number of tomato-infecting begomoviruses increased from three in 1970 to 17 in the 1990s. The effect of selection imposed by

## SELECTED PUBLICATIONS

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SEAL, S.E., JEGER, M.J. and VAN DEN BOSCH, F. (2006) Research priorities to assist understanding the factors controlling the global emergence of whitefly-transmitted diseases. *Advances in Virus Research* (in press).

VAN DEN BOSCH, F., AKUDIBILAH, G., SEAL, S. and JEGER, M.J. (2006) Host resistance and the evolutionary response of plant viruses. *Journal of Applied Ecology* (in press).

*New CMD on upper leaves of cassava (left); severe CMD (right) (photos: James Legg)*

begomovirus management on the evolution of new virus types/species is presently unknown.

Previous work on whitefly and whitefly-transmitted virus disease management has focused on specific problems in restricted geographical regions, with less attention being paid to strategic concepts of management. The aim of this project was to provide a strategic analysis to identify the potential consequences of pest- and disease-management measures on short-term evolution of *B. tabaci* and begomoviruses in cropping systems of developing countries.

## ACHIEVEMENTS

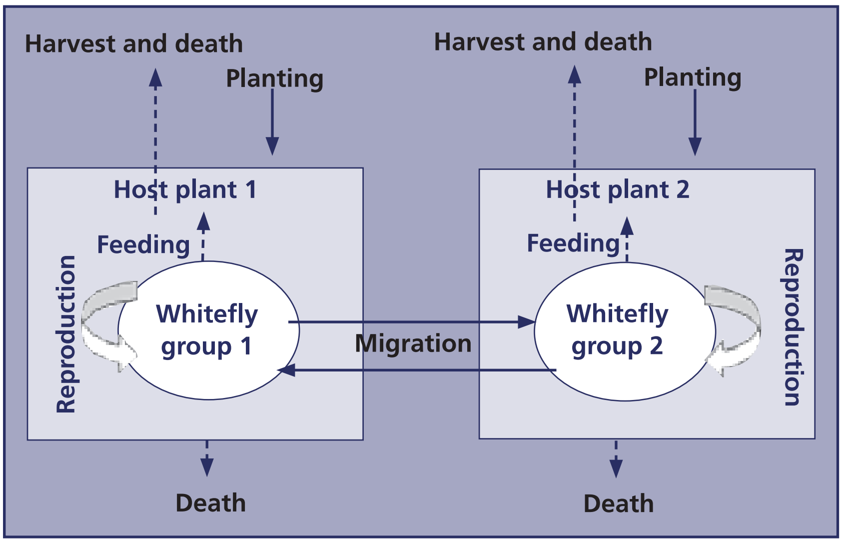
A review of the literature identified that begomovirus genetic diversity is extremely complex, and there is still much to be answered about how the different genomic components and satellite molecules interact. The vector populations are also more diverse than previously realised, and more research is needed on how this diversity affects the evolution of more virulent begomovirus strains/species. The review has identified the most pressing research needs in this area, together with studies on the control of host-gene silencing of virus genes, and the effects of particular cropping mixtures on virus genetic diversity.

A model was formulated and analysed to study the evolution of *B. tabaci* (bio)types under the influence of the introduction of a new crop or variety; the use of pesticides; and the structure of the cropping system, comparing large-scale monocultures with intercropping. Three life-history traits that might undergo evolution were studied: the feeding rate of whitefly on the crop species/varieties; the efficiency of conversion of food into offspring; and the death rate of whitefly on each crop.

Using the adaptive dynamics methodology of evolutionary ecology, this work has demonstrated the following.

- Whether new (bio)types will evolve depends strongly on the trait under evolution. This result is unexpected, and has attracted the attention of the evolutionary ecology and whitefly research communities.
- When feeding rate is the evolving trait, new (bio)types can evolve when a newly introduced crop reaches a critical acreage. When food conversion efficiency is the evolving trait, and no whiteflies are brought in with the new crop, no new (bio)type will evolve.
- Although there are other very good reasons for intercropping, no difference was found between large monocultures and intercropping systems in exerting evolutionary pressure for the evolution of whitefly (bio)types.

The project studied, among other questions, the evolutionary consequences of introducing resistant and tolerant cultivars. A model has been developed to analyse the effects of introducing a resistant cultivar on the evolution of the virus titre built up in the plant. Four types of resistance/ tolerance mechanism have been distinguished. When the virus has




*Schematic representation of the model, showing the relationship between host plants and whiteflies*

Bemisia tabaci *affects over 600 host species worldwide (photo: Stephen Ausmus, courtesy of US Department of Agriculture, Agricultural Research Service, www.ars.usda.gov)*

had sufficient time to adapt to resistance, two groups of effects of using resistant cultivars on the dynamics of the disease are found.

The first group, including inoculation resistance and acquisition resistance, does not put a selection pressure on the virus. This suggests that the virus titre in infected plants does not change; also, the density of healthy plants in the system increases. This means that yield loss due to the disease will not change when inoculation-resistant or acquisition-resistant cultivars are used. These types of resistance are good candidate disease-management methods for sustainable agricultural systems.

The second group, including tolerance and virus titre-reducing resistance, do put a selection pressure on the virus to evolve towards higher virus multiplication rates. For tolerant cultivars, this suggests that the plant virus titre increases. Whether this has a negative effect on crop yield depends on the balance between the yield gain due to the tolerance of the plants, and the yield reduction due to the increased virus titre. For plants expressing virus titre-reducing resistance, the evolutionary response of the virus causes the within-plant virus titre to evolve back to the titre of the non-resistant cultivar from which it was derived. Also, the density of healthy plants will evolve back towards the density of a non-resistant cultivar. The cultivars from this second group are thus not durable, in the sense that they put an evolutionary pressure on the virus, which might reduce the effectiveness of the tolerance/resistance.

Whether tolerant and virus titre-reducing cultivars have a contribution to make depends on a number of factors. A tolerant cultivar might still have a positive effect on yield, even when the virus has evolved a new evolutionarily stable strategy, simply because the tolerance provides a sufficient amount of additional damage reduction. Or it could be that the evolutionarily stable virus-multiplication rate is outside the attainable range for the virus under consideration. Finally, the time the virus takes to evolve towards a new evolutionarily stable virus-multiplication rate is also important.

While this work does not suggest that tolerant and virus titre-reducing cultivars have no contribution to make to the management of virus diseases, it does suggest that there are potential problems with the use of such cultivars that need to be considered to maximise the effectiveness of resistance. The inoculation-resistant and acquisition-resistant cultivars do not have such problems.

## FURTHER APPLICATION

The project's findings have been passed on to researchers of the Consultative Group on International Agricultural Research collaborative Tropical Whitefly IPM Project (www.tropicalwhiteflyipm project.cgiar.org). During the IX International Plant Virus Epidemiology Symposium (Lima, Peru, April 2005), a workshop was held to discuss the work further and develop future research plans.

There is, however, very little research developing to elucidate the links between molecular genetics of begomoviruses and the epidemiological characteristics of the diseases caused by these viruses, or into evolving life-history traits in *B. tabaci*. These should be key future research areas.

With further studies it should be possible to develop methods for the selection of resistant cultivars, and to select crop- and disease-management methods that do not provoke the virus to evolve into more harmful variants. Future work needs to concentrate on the robustness of the present findings for other evolving virus traits; to develop experimental methodologies to dissect the contribution of various types of crop resistance in resistant cultivars; and to develop selection programmes based on these methods.

# Acronyms and abbreviations

| | |
|---|---|
| AAU | Assam Agricultural University, India |
| ABC | armoured bush cricket |
| ACMV | African cassava mosaic virus |
| ADB | Asian Development Bank |
| AEATRI | Agricultural Engineering and Appropriate Technology Research Institute, Uganda |
| AFLP | amplified fragment length polymorphism |
| AHI | African Highland Initiative, Uganda |
| AID-Comilla | Association for Integrated Development Comilla, Bangladesh |
| ANGRAU | Acharya NG Ranga Agricultural University, India |
| APEP | Agricultural Productivity and Extension Project, Uganda (formerly IDEA) |
| ARC | Agricultural Research Council, South Africa |
| AREX | Department of Agricultural Research and Extension, Zimbabwe |
| ARI | Agricultural Research Institute, Tanzania |
| ARM | Athi River Mining, Kenya |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa |
| ASDP | Agricultural Sector Development Programme, Tanzania |
| ATNESA | Animal Traction Network for Eastern and Southern Africa |
| AT-Uganda | Appropriate Technology-Uganda |
| AVRDC | The World Vegetable Center (formerly Asian Vegetable Research and Development Center) |
| BARI | Bangladesh Agricultural Research Institute |
| BCPC | British Crop Production Council |
| BGM | Botrytis grey mould |
| BRRI | Bangladesh Rice Research Institute |
| *Bt* | *Bacillus thuringiensis* |
| BUCADEF | Buganda Cultural and Development Foundation, Uganda |
| CABI ARC | CAB International Africa Regional Centre, Kenya |
| CBO | community-based organisation |
| CBSD | cassava brown streak disease |
| CEH | Centre for Ecology and Hydrology, UK |
| CFC | Common Fund for Commodities |
| CGIAR | Consultative Group on International Agricultural Research |
| CIAT | Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture), Colombia |
| CIAT | Centro de Investigacion Agricola Tropical (Center for Research in Tropical Agriculture), Bolivia |
| CILSS | Comité Permanent Inter-Etats de Lutte Contre la Sécheresse dans le Sahel |
| CIMMYT | Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center), Mexico |
| CIP | Centro Internacional de la Papa (International Potato Center), Peru |
| CIRAD | Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France |
| CISH | Central Institute for Subtropical Horticulture, India |
| CMD | cassava mosaic disease |
| CMGs | cassava mosaic geminiviruses |
| COARD | Client Oriented Agricultural Research and Dissemination project, Uganda |
| COLEACP | Europe–Africa/Caribbean/Pacific Liaison Comité (Comité de Liaison Europe–Afrique/Caraïbes/Pacifique) |
| CORI | Coffee Research Institute, Uganda |
| CPHP | Crop Post-Harvest Programme, DFID |
| CRI | Crops Research Institute, Ghana |
| CRIG | Cocoa Research Institute, Ghana |
| CRIN | Cocoa Research Institute, Nigeria |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation, Australia |
| CSL | Central Science Laboratory, UK |
| CURE | Consortium for Unfavorable Rice Environments, IRRI |

| | |
|---|---|
| DAE | Department of Agricultural Extension, Bangladesh |
| DANIDA | Danish International Development Agency |
| DAP | draught animal power |
| DAR | Department of Agricultural Research, Botswana |
| DAS-ELISA | double-antibody sandwich enzyme-linked immunosorbent assay |
| DFID | Department for International Development, UK |
| DRC | Democratic Republic of Congo |
| EACMV | East African cassava mosaic virus |
| ECABREN | Eastern and Central Africa Bean Research Network |
| ECAMAW | Eastern and Central Africa Maize and Wheat research network of ASARECA |
| ECARSAM | Eastern and Central African Research on Sorghum and Millet Network |
| EIA | environmental impact assessment |
| ELISA | enzyme-linked immunosorbent assay |
| EMBRAPA | Empresa Brasileira de Pesquisa Agropecuária, Brazil |
| EU | European Union |
| EUMESAT | European Organisation for the Exploitation of Meteorolgical Statelites |
| EUREP | Euro-Retailer Produce Working Group |
| EZCORE | Eastern Zone Client Oriented Research and Extension Project, Tanzania |
| FAO | Food and Agriculture Organization of the United Nations, Italy |
| FFAI | Food For All International, Nigeria |
| FFS | farmer field school |
| FIPS-Africa | Farm Input Promotions-Africa Ltd, Kenya |
| FIT | Fortaleciendo la Innovacion [Strengthening Institutional Innovation] |
| FOCAM | Fomentando Cambios [Promoting Changes] |
| GAP | Good Agricultural Practices |
| GAU | Gujarat Agricultural University, India |
| GBPUAT | GB Pant University of Agriculture and Technology, India |
| GIS | geographic information systems |
| GLS | grey leaf spot (of maize) |
| GOAN | Ghana Organic Agriculture Network |
| GOES | geo-stationary earth-orbiting satellite |
| GTZ | Deutches Gesellscaft für Technische Zusammenarbeit, Germany |
| *Hear*NPV | *Helicoverpa armigera* nucleo-polyhedrovirus |
| HIMA | Hifadhi Mazingiira (Conserve the Environment) |
| IARC | International agricultural research centre |
| IARI | Indian Agricultural Research Institute |
| ICAR | Indian Council of Agricultural Research |
| ICIPE | International Centre for Insect Physiology and Ecology |
| ICM | integrated crop management |
| ICOSAMP | Information Core for Southern African Migrant Pests |
| ICRAF | World Agroforestry Centre (formerly International Centre for Research in Agroforestry, Kenya) |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics, India |
| IDEA | Investing in the Development of Export Agriculture Project, Uganda (now APEP) |
| IFAD | International Fund for Agricultural Development |
| IIHR | Indian Institute of Horticultural Research |
| IITA | International Institute of Tropical Agriculture, Nigeria |
| IIVR | Indian Institute of Vegetable Research |
| ILRI | International Livestock Research Institute, Kenya |
| INADES-Formation | Institut Africain pour le Développement Economique et Social – Centre Africain de Formation, Tanzania |
| INCOPED | International Permanent Working Group for Cocoa Pests and Diseases |
| INIA | Instituto Nacional de Investigacão Agronómica (National Institute for Agronomic Research), Mozambique |
| INNOVA | Strengthening technical innovation systems in potato-based agriculture in Bolivia |
| INRAB | Institut National des Recherches Agicoles du Bénin (National Institute for Agricultural Research, Bénin) |
| IOBC | International Organization for Biological and Integrated Control |
| IPGRI | International Plant Genetic Resources Institute, Italy |
| IPM | integrated pest management |
| IPPM | integrated pest and production management |

| | |
|---|---|
| IR | imidazolinone-resistant (maize) |
| IRAD | Institut de Recherche Agricole pour le Développement, Cameroun (Institute of Agricultural Research for Development) |
| IRLCO-CSA | International Red Locust Control Organisation for Central and Southern Africa |
| IRM | insecticide resistance management |
| IRRC | Irrigated Rice Research Consortium |
| IRRI | International Rice Research Institute |
| ITK | indigenous technical knowledge |
| KAPP | Kenya Agricultural Productivity Project |
| KARI | Kenya Agricultural Research Institute |
| KASPPA | Kapchorwa Seed Potato Producers' Association, Uganda |
| KATC | Kilimanjaro Agricultural Training Centre, Tanzania |
| KATRIN | Kilombero Agricultural Training and Research Institute, Tanzania |
| KAU | Kerala Agricultural University, India |
| KEPHIS | Kenya Plant Health Inspection Service |
| KFRI | Kerala Forest Research Institute, India |
| KIOF | Kenya Institute of Organic Farming |
| LPP | Livestock Production Programme, DFID |
| MERCOSUR | Common Market of the Southern Cone |
| MIP | Maize Improvement Programme, Tanzania |
| MoAC | Ministry of Agriculture and Cooperatives, Nepal |
| MSV | maize streak virus |
| MSVD | maize streak virus disease |
| MUK | Makerere University Kampala, Uganda |
| NAADS | National Agricultural Advisory Service, Uganda |
| NAARI | Namulonge Agricultural and Animal Production Research Institute, Uganda |
| NARC | Nepal Agricultural Research Council |
| NARES | national agricultural research and extension services |
| NARI | Naliendele Agricultural Research Institute, Tanzania |
| NARL | National Agricultural Research Laboratory, KARI, Kenya |
| NARO | National Agricultural Research Organisation, Uganda |
| NARS | national agricultural research systems |
| NCAP | National Centre for Agricultural Economics and Policy Research |
| NDUAT | Narendra Deva University of Agriculture and Technology, India |
| NGO | non-governmental organisation |
| NPA | Norwegian People's Aid |
| NRI | Natural Resources Institute, University of Greenwich, UK |
| OB | occlusion bodies |
| OBEPAB | Organisation Béninoise pour la Promotion de l'Agriculture Biologique, (Organisation for the Promotion of Biological Agriculture, Bénin) |
| PABRA | Pan-African Bean Research Alliance |
| PADEP | Participatory Development and Empowerment Project, Tanzania |
| PC | production committee |
| PCR | polymerase chain reaction |
| PCS | Pest Control Service, Tanzania |
| PDC | parish development committee |
| PETRRA | Poverty Elimination Through Rice Research Assistance |
| *Plxy*GV | *Plutella xylostella* granulovirus |
| PNC | penicillinase [detection system] |
| PPRI | Plant Protection Research Institute, AREX, Zimbabwe |
| PPRI | Plant Protection Research Institute, South Africa |
| PPSMV | pigeonpea sterility mosaic virus |
| PPSMVD | pigeonpea sterility mosaic virus disease |
| PRA | participatory rural appraisal |
| PRAPACE | Programme Regional d'Amelioration de la Pomme de Terre et de la Patate Douce en Afrique Centrale et de l'Est, Uganda (Regional Potato and Sweetpotato Improvement Network in Eastern and Central Africa) |
| PREA | participatory research and extension approach |
| PROINPA | Fundación 'Promoción e Investigación de Productos Andinos' (PROINPA), Bolivia |

| | |
|---|---|
| PRONAF | Programa Nacional de Fortalecimento da Agricultura Familiar |
| PROVA | People's Resources Oriented Voluntary Association, Bangladesh |
| PSMD | pigeonpea sterility mosaic disease |
| *Px*GV | *Plutella xylostella* granulovirus |
| RAU | Rajendra Agricultural University, India |
| RDT | Rural Development Trust, India |
| REFSO | Rural Energy and Food Security Organization, Kenya |
| RFLP | restriction fragment length polymorphism |
| RNRRS | Renewable Natural Resources Research Strategy, DFID |
| RT–PCR | reverse transcription–polymerase chain reaction |
| SAARI | Serere Agricultural and Animal Production Research Institute, NARO, Uganda |
| SABRN | Southern African Bean Research Network, Malawi |
| SADC | Southern African Development Community |
| SAFFN | South Asia Fruit Fly Network |
| SARRNET | Southern Africa Root crops Research Network |
| SCFT | Smallholder Coffee Farmers Trust, Malawi |
| SCRI | Scottish Crop Research Institute |
| SGRR(PG) | Sri Guru Ram Rai (Post Graduate) College of Hemwati Nandan Bahguna Garhwal University, India |
| SIBTA | El Sistema Boliviano de Tecnologia Agropecuaria [Bolivian competitive funding system] |
| SMEs | small and medium-sized enterprises |
| *Spex*NPV | *Spodoptera exempta* nucleopolyhedrovirus |
| SPS | seed-plot system |
| SPVD | sweet potato virus disease |
| SRI | Sugarcane Research Institute, Tanzania |
| STAAD | Society for Transforming Agriculture and Alternatives in Development, India |
| STCP | Sustainable Tree Crops Programme, Cameroon |
| TME | tropical *Manihot esculenta* series |
| TMS | tropical *Manihot* species |
| ToLCVD | tomato leaf curl virus disease |
| TSBF-CIAT | Tropical Soil Biology and Fertility Institute, CIAT, Kenya |
| UASB | University of Agricultural Sciences Bangalore, India |
| UMSS | Universidad Mayor de San Simon (San Simón University), Bolivia |
| UNBRP | Uganda National Banana Research Programme |
| UPOV | Union Internationale pour la Protection des Obtentions Vegetales (International Union for the Protection of New Varieties of Plants) |
| USAID | United States Agency for International Development |
| VIC | village information centre |
| VITA A | Vitamin A Initiative for Africa |
| WADI | Windows Armyworm Database Interface [software] |
| Warwick HRI | [formerly Horticulture Research International] |
| WHO | World Health Organization |
| *Xcc* | *Xanthomonas campestris* pv. *campestris* |
| ZAR | South African Rand |
| ZFU | Zimbabwe Farmers' Union |

# Project list 2000–05

| R No. | Project title | Years | Location | Page |
|---|---|---|---|---|
| R6580 | Non-chemical management of banana nematodes in East Africa | 1996–2000 | Kenya | |
| R6582 | Epidemiology, toxicology and management of the maize ear-rot complex in African farming systems | 1996–2000 | Kenya, Malawi | |
| R6629 | Biological control of bacterial wilt of potato in Kenya and Pakistan | 1996–2000 | Kenya, Pakistan | |
| R6691 | Control of yam diseases in forest margin farming systems in Ghana | 1996–2000 | Ghana | |
| R6695 | Developing strategies for the control of *Parthenium* weed in India using fungal pathogens | 1996–2000 | India | |
| R6735 | Development of biocontrol strategy for the management of weed *Mikania micrantha* in tree-crop based farming systems in India | 1996–2000 | India | |
| R6737 | Management of *Cyperus* in smallholder farming systems on Vertisols and vertic clay soils | 1996–2000 | Ghana | |
| R6764 | Environmentally acceptable crop protection strategies based on the improved use of pesticides and adoption of integrated pest management strategies by smallholder farmers in Zimbabwe | 1997–2001 | Zimbabwe | |
| R6766 | Epidemiology and population structure of *Phytophthora* species causing diseases of coconut in Indonesia | 1996–2000 | Indonesia | |
| R6788 | Development of an outbreak forecasting tool for the Senegalese grasshopper, *Oedaleus senegalensis*, using satellite and ecological data | 1997–2000 | Cameroon | |
| R6807 | An investigation of pesticide and microbial interactions on coffee as a means of developing an IPM strategy for economically important coffee pests in smallholder farming systems in Malawi | 1996–2000 | Malawi | |
| R7071 | Development of improved pest control technologies for dry season vegetables in the coastal saline zone of north-eastern India | 1997–2001 | India | |
| R7189 | Cultivar competitiveness and interactions with on-farm weed priming for integrated weed management | 1998–2001 | Global | |
| R7249 | Development of mycoinsectides and pheromones for cocoa mirids | 1998–2002 | Ghana | |
| R7267 | Principal pod-boring pests of tropical legume crops: economic importance, taxonomy, natural enemies and control | 1998–2002 | India, Malawi, Níger, Brazil | |
| R7296 | Pest and natural enemy interactions in low-input rice cropping systems | 1998–2001 | Bangladesh | |
| R7299 | An evaluation of the promotion and uptake of microbial pesticides in developing countries by resource-poor farmers | 1998–2002 | India, Thailand | |
| R7325 | The development of integrated weed management strategies for hillsides in the valleys of Cochabamba, Bolivia | 1999–2002 | Bolivia | |
| R7331 | Minimising the economic and sociological impact of *Phalaris minor* in rice/wheat ecosystems: importance, taxonomy, natural enemies and control | 1999–2002 | India, Bangladesh | |
| R7337 | The optimisation and dissemination of a molecular identification module for *Phytophthora* species | 1999–2000 | Ghana, Uganda | |
| R7345 | Management of weedy rices in Africa | 1999–2002 | Ghana, Mali, Tanzania | |
| R7346 | Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India | 1999–2002 | India | |
| R7347 | Fate of herbicide residues in irrigated rice systems | 1999–2000 | India, Bangladesh, Pakistan | |
| R7372 | Development of a methodology for assessing the impact of rodents on rural household food security, health and nutrition | 1999–2002 | Mozambique | |
| R7377 | Development of sustainable weed management systems in direct-seeded, irrigated rice | 1999–2002 | India | |
| R7401 | Improving production in the Teso farming systems through the development of sustainable draught animal technologies | 1999–2004 | Uganda | 54 |

| R No. | Project title | Years | Location | Page |
|---|---|---|---|---|
| R7403 | Pest management in horticultural crops: an integrated approach to vegetable pest management with the aim of reducing reliance on pesticides in Kenya | 1999–2002 | Kenya | |
| R7404 | Socio-economic study of the uptake of herbicide technology in maize cropping systems | 1999–2000 | Kenya, Uganda | |
| R7405 | Development of weed management in maize-based cropping systems | 1999–2002 | Kenya, Uganda | |
| R7428 | Biology and control of armoured bush crickets in southern Africa | 1999–2002 | Botswana, South Africa | |
| R7429 | The development and management strategies for maize streak virus disease | 1999–2000 | Uganda | |
| R7441 | Development of pheromone trapping for monitoring and control of the legume pod borer, *Maruca vitrata* (syn. *testulalis*) by smallholder farmers in West Africa | 1999–2003 | Ghana, Benin | |
| R7445 | Groundnut rosette disease management | 1999–2002 | Uganda | 57 |
| R7449 | Development of biorational brassica IPM in Kenya | 1999–2002 | Kenya | |
| R7452 | Characterisation of the casual virus of pigeonpea sterility mosaic disease – A step towards attaining sustainability of pigeonpea production in the Indian subcontinent | 1999–2002 | India, China, Nepal | 147 |
| R7460 | Sustainable management and molecular characterisation of *Bemisia tabaci* and tomato leaf curl virus on tomato in India (phase II) | 1999–2002 | India | |
| R7462 | The development of integrated management systems for the control of pests and diseases in the potato systems of the Mesothermic Valleys of Bolivia | 1999–2002 | Bolivia | |
| R7471 | Developing weed management strategies for rice-based cropping systems in Bangladesh | 1999–2002 | Bangladesh | |
| R7472 | Integrated management of root-knot nematodes on vegetables in Kenya | 1999–2002 | Kenya | |
| R7473 | Weed management in wetland fields | 1999–2002 | Zimbabwe | |
| R7474 | Weed management options for cotton-based systems of the Zambezi Valley | 1999–2002 | Zimbabwe | |
| R7478 | Management strategies for banana streak virus: variation of BSV in Uganda as an adjunct to diagnosis and epidemiology | 1999–2001 | Uganda | |
| R7479 | Assessment and significance of tree pests in Bolivia | 1999–2001 | Bolivia | |
| R7488 | Study of factors affecting the uptake and adoption of outputs of crop protection research in banana-cropping systems in Uganda | 1999–2000 | Uganda | |
| R7489 | Study of factors affecting the uptake and adoption of outputs of crop protection research in maize systems in eastern Africa | 1999–2000 | Kenya, Uganda | |
| R7490 | Integrated pest and soil fertility management | 1999–2000 | Kenya, Tanzania | |
| R7491 | *Nacobbus aberrans* and weeds in Bolivian potato fields: environmental consequences of current and future nematode control options | 2000 | Bolivia | |
| R7492 | Promotion of and technical support for methods of controlling whitefly-borne viruses in sweet potato in East Africa | 1999–2002 | Uganda, Tanzania | |
| R7500 | Analysis of farmers' decision making in pest management | 1999–2000 | Global | |
| R7503 | Integrating pest management and soil fertility management | 1999–2000 | Ghana | |
| R7504 | Study of factors affecting the uptake and adoption of outputs of crop protection research on yams in Ghana | 1999–2000 | Ghana, Nigeria | |
| R7505 | Strategies for the sustainable deployment of cassava mosaic disease resistant cassava in East Africa | 1999–2002 | Uganda, Tanzania, Kenya | |
| R7506 | Review of technical and institutional options for sorghum grain mould management and the potential impact on the poor | 1999–2000 | India | |
| R7512 | Factors affecting uptake and adoption of outputs of crop protection research in peri-urban vegetable systems in Kenya | 1999–2000 | Kenya | |
| R7513 | Factors affecting the uptake and adoption of crop research in vegetable systems in India/Bangladesh/Nepal | 1999–2000 | India, Bangladesh, Nepal | |
| R7518 | An investigation into the epidemiology and control of fungal pathogens of sorghum in semi-arid production systems in East Africa | 1999–2002 | Kenya, Tanzania, Uganda | |

| R No. | Project title | Years | Location | Page |
|---|---|---|---|---|
| R7529 | Management strategies for banana streak virus; epidemiology, vector studies and control of banana streak virus in East Africa highland bananas | 1999–2003 | Uganda, Kenya | |
| R7552 | Strategies for development and deployment of durable blast resistance in West Africa | 1999–2003 | Côte d'Ivoire, Ghana | |
| R7561 | Factors affecting the uptake and adoption of crop research in rice systems in West Africa | 2000 | Ghana, West Africa | |
| R7563 | Management of cassava brown streak disease and mosaic disease in eastern and southern Africa | 1999–2002 | Tanzania, Mozambique, Malawi | |
| R7564 | Integrated management of *Striga* species on cereal crops in East Africa | 2000–2003 | Tanzania, Uganda | |
| R7565 | Participatory breeding of superior, mosaic disease-resistant cassava | 2000–2003 | Ghana | |
| R7566 | Management strategies for maize grey spot (*Cercospora zeae-maydis*) in Kenya and Zimbabwe | 2000–2003 | Zimbabwe, Kenya, Swaziland | 69 |
| R7567 | Integrated management of banana diseases in Uganda | 2000–2003 | Uganda | 3 |
| R7568 | Characterisation and epidemiology of root rot diseases caused by *Fusarium* and *Pythium* spp. in beans | 2000–2003 | Uganda | 31 |
| R7569 | Participatory promotion of disease-resistant and farmer-acceptable *Phaseolus* beans in the Southern Highlands of Tanzania | 2000–2003 | Tanzania | 36 |
| R7570 | Determining the nature and function of crop associated biodiversity for sustainable intensification of rice-based production systems | 2000–2003 | Vietnam, the Philippines, Côte d'Ivoire, Bangladesh | |
| R7571 | Management of virus diseases of important vegetable crops in Kenya | 2000–2003 | Kenya | |
| R7572 | Management of key insect pests of sorghum in southern and eastern Africa: developing IPM approaches with expert panels | 2000–2003 | Kenya | |
| R7576 | Factors affecting uptake and adoption of outputs research in rice systems in India | 2000 | India | |
| R7579 | Strategies for forage production and erosion control as a complement to hillside weed management | 2000–2001 | Bolivia | |
| R7585 | Use of transgenic pest-resistant crops | 2000 | Global | |
| R7587 | Field guide and posters of key natural enemies of vegetable pests in southern and eastern Africa: production and dissemination in Zimbabwe | 2000–2001 | Zimbabwe | |
| R7778 | Rice sheath blight complex caused by *Rhizoctonia* species: pathogen epidemiology and management strategies | 2000–2003 | Bangladesh | 159 |
| R7779 | Forecasting outbreaks of the brown locust in southern Africa | 2000–2003 | South Africa | |
| R7796 | Cassava brown streak virus, virus isolates and the application of the diagnostic test | 2000–2001 | Tanzania, Malawi, Kenya, Mozambique | |
| R7809 | Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India: a step towards improving health of humans and livestock | 2000–2002 | India | |
| R7813 | Sustainable control of the cotton bollworm, *Helicoverpa armigera*, in small-scale cotton production systems | 2000–2004 | India | 157 |
| R7818 | Development of biologically based control strategies for environmentally sustainable control of red locust in central and southern Africa | 2000–2004 | Kenya | |
| R7821 | Promotion of an integrated pest management programme for pigeonpea in India and East Aftica | 2000–2001 | India | |
| R7858 | Promoting potato seed-tuber management for increased ware yields in Kenya, Uganda and the Republic of South Africa | 2000–2001 | Kenya, Uganda, South Africa | |
| R7876 | Investigations into the epidemiology of Kalimatan wilt of coconuts in Indonesia | 2001–2004 | Indonesia | |
| R7885 | Promoting the adoption of improved disease and pest management technologies in chickpea by poor farmers in mid hills and hillside cropping systems in Nepal | 2000–2003 | Nepal, India | 152 |
| R7890 | Establishment of an 'Information Core for Southern African Migrant Pests' (ICOSAMP) | 2000–2003 | Southern Africa | |

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|---|---|---|---|---|
| R7891 | Ecology and management of rice hispa (*Dicladispa armigera*) in Bangladesh | 2000–2004 | Bangladesh | 162 |
| R7923 | Farmers' access to information and the uptake of IPM in pigeonpea | 2000–2001 | India | |
| R7942 | IPM for smallholder coffee in Malawi | 2001–2002 | Malawi | |
| R7951 | Testing biological control of pest termites for maize-based farming systems in Uganda | 2000–2001 | Uganda | |
| R7954 | Novel technologies for the control of the African armyworm *Spodoptera exempta* on smallholder cereals in East Africa developed, evaluated and promoted | 2001–2004 | Tanzania | 93 |
| R7955 | Strategies for feeding smallholder dairy cattle in intensive maize forage production systems and implications for integrated pest management | 2001–2004 | Kenya | 82 |
| R7960 | Public-private partnerships for development and implementation of entomopathogenic viruses as bioinsecticides for key lepidopteran pests in Ghana and Benin, West Africa | 2001–2004 | Ghana, Benin | 110 |
| R7965 | Promotion of integrated pest management strategies of major insect pests of *Phaseolus* beans in hillsides systems in eastern and southern Africa | 2001–2005 | Tanzania, Kenya, Malawi, Uganda | 39 |
| R7966 | Identifying the factors causing outbreaks of armyworm as part of improved monitoring and forecasting systems | 2000–2004 | Kenya, Tanzania | 96 |
| R7967 | Forecasting movements and breeding of the red-billed quelea bird in southern Africa and improved control strategies | 2001–2003 | Southern Africa | 101 |
| R7972 | Integrated management of the banana weevil in Uganda | 2001–2004 | Uganda, Kenya | 1 |
| R8026 | Commercial adoption of pheromones as a component in the integrated crop management of rice in Bangladesh | 2001–2003 | Bangladesh | 165 |
| R8030 | Finger millet blast in East Africa: pathogen diversity and disease management strategies | 2001–2004 | Uganda, Kenya, India | 52 |
| R8040 | Rapid multiplication and distribution of sweet potato varieties with high yielding and β-carotene content | 2001–2003 | Uganda | 23 |
| R8041 | Sustainable integrated management of whiteflies as pests and vectors of plant viruses in the tropics: Phase 2 – Network strengthening, pest and disease dynamics and IPM component research | 2001–2004 | Uganda, Tanzania El Salvador, Guatemala, Ecuador, Colombia | 182 |
| R8044 | Integrated management of major insect pests of potatoes in hillside systems in the Cochabamba region of Bolivia | 2001–2004 | Bolivia, Peru | |
| R8089 | Management of fruit flies (Diptera: Tephritidae) in India | 2001–2005 | India | 135 |
| R8104 | Promoting potato seed-tuber management for increased ware yields in Kapchorwa District, eastern Uganda | 2002–2005 | Uganda | 107 |
| R8105 | Farmer-led multiplication of rosette-resistant groundnut varieties for eastern Uganda | 2002–2005 | Uganda | 59 |
| R8106 | Promotion of on-farm small-scale seed potato production in low input farming communities in Kabale District, Uganda | 2002–2003 | Uganda | |
| R8167 | Promotion of sustainable sweet potato production and post-harvest management through farmer field schools in East Africa | 2002–2005 | Uganda, Kenya | 26 |
| R8182 | Strengthening technical innovation systems in potato-based agriculture in Bolivia (INNOVA) | 2002–2005 | Bolivia | 184 |
| R8184 | Ecologically based rodent management for diversified rice-based cropping systems | 2002–2005 | Bangladesh | 179 |
| R8187 | Development of IPM strategies for coconut mite, *Aceria guerreronis*, with emphasis on fungal pathogens | 2002–2005 | Sri Lanka | |
| R8188 | Epidemiology and variability of *Gibberella xylarioides*, the coffee wilt pathogen | 2002–2004 | Uganda, Ethiopia, Tanzania | 42 |
| R8190 | Technology transfer and promotion of ecologically based and sustainable rodent control strategies in South Africa | 2002–2005 | South Africa, Mozambique | 130 |
| R8191 | Promoting improved crop management in cotton and cereal-based cropping systems in semi-arid areas | 2002–2005 | Zimbabwe | 88 |
| R8194 | On-farm verification and promotion of green manure for enhancing upland rice productivity on *Striga*-infested fields in Tanzania | 2002–2005 | Tanzania | 64 |

| R No. | Project title | Years | Location | Page |
|---|---|---|---|---|
| R8197 | Development and promotion of appropriate IPM strategies for smallholder cotton in Uganda | 2002–2005 | Uganda | 90 |
| R8198 | Development and promotion of wild rice management strategies for the lowlands of southern Tanzania | 2002–2005 | Tanzania | 61 |
| R8204 | ICPM for smallholder coffee in Malawi | 2002–2005 | Malawi | |
| R8205 | Characterisation of the causal virus of pigeonpea sterility mosaic disease: a further step towards attaining sustainability of pigeonpea production in the Indian subcontinent | 2002–2004 | India, Nepal, China | 149 |
| R8212 | Integrated pest and soil management to combat *Striga*, stem borers and declining soil fertility in the Lake Victoria basin | 2002–2005 | Kenya, Uganda Tanzania | 79 |
| R8215 | Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowland maize systems | 2002–2005 | Tanzania | 85 |
| R8217 | Production of baculovirus to control lepidopteran pests in vegetable crops in peri-urban and rural areas | 2002–2005 | Kenya | |
| R8218 | Production of *Pasteuria penetrans* to control root-knot nematodes (*Meliodogyne* spp.) | 2002–2004 | Kenya | |
| R8219 | Improved access to appropriate farm inputs for integrated maize crop management by small-scale farmers in Embu and Kirinyaga districts, Kenya | 2003–2005 | Kenya | 76 |
| R8220 | Improving farmers' access to and management of disease-resistant maize cultivars in the Southern Highlands of Tanzania | 2002–2005 | Tanzania | 73 |
| R8222 | Adaptive evolution within *Bemisia tabaci* and associated Begomoviruses: A strategic modelling approach to minimising threats to sustainable production systems in developing countries | 2002–2005 | Global | |
| R8227 | Promotion of control measures for cassava brown streak disease | 2003–2005 | Tanzania, Mozambique, Malawi, Kenya | 20 |
| R8228 | Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: Implementation Phase | 2002–2005 | India | 132 |
| R8233 | Promotion of integrated weed management for direct-seeded rice in the Gangetic Plains of India | 2003–2005 | India | 173 |
| R8234 | Promotion of cost-effective weed management practices for lowland rice in Bangladesh | 2003–2005 | Bangladesh | 176 |
| R8243 | Working with farmers to control sweet potato virus disease in East Africa | 2002–2005 | Uganda, Tanzania | 28 |
| R8247 | Promotion and impact assessment of tomato leaf curl virus disease resistant tomatoes: phase III of sustainable management and molecular characterisation of *Bemisia tabaci* and tomato leaf curl virus (ToLCV) on tomato in India | 2003–2005 | India | 139 |
| R8253 | Biology and control of armoured bush crickets in southern Africa | 2002–2003 | Botswana | 105 |
| R8278 | Evaluation and promotion of crop protection practices for 'clean' seed yam production systems in Central Nigeria | 2003–2005 | Nigeria | 11 |
| R8281 | Linking the demand for, and supply of, agricultural production and post-harvest information in Uganda | 2003–2005 | Uganda | 125 |
| R8284 | Biological control of root-knot nematodes | 2002–2003 | Kenya | |
| R8296 | Promotion of sustainable approaches for the management of root-knot nematodes on vegetables in Kenya | 2003–2005 | Kenya | 113 |
| R8297 | Development of private sector service providers for the horticultural industry in Kenya | 2003–2005 | Kenya | 116 |
| R8298 | Aflatoxin contamination in groundnut in southern India: raising awareness and transferring and disseminating technologies to reduce aflatoxin | 2003–2005 | India | 143 |
| R8299 | Accelerated uptake and impact of CPP research outputs in Kenya | 2003–2005 | Kenya | 128 |
| R8300 | Implementing pheromone traps and other new technologies for control of cowpea insect pests in West Africa through farmer field schools | 2003–2005 | Benin, Ghana | 50 |

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|---|---|---|---|---|
| R8301 | Archiving data from integrated pest and disease management projects within the Uganda National Banana Research Programme | 2003–2004 | Uganda | 9 |
| R8302 | Participatory breeding of superior mosaic disease-resistant cassava: validation, promotion and dissemination | 2003–2005 | Ghana | 14 |
| R8303 | Maximising, disseminating and promoting the benefits to farmers of cassava varieties resistant to cassava mosaic disease | 2003–2005 | Uganda, Tanzania | 17 |
| R8304 | Technical support for SME supplying pheromone-based pest control technologies in South Asia | 2003–2004 | India, Bangladesh, Sri Lanka | 171 |
| R8309 | Coconut lethal yellowing disease: development of new diagnostic tools and laboratory support to promote their application | 2003–2005 | Ghana, Tanzania, Jamaica, Mexico, Honduras | 118 |
| R8312 | Promotion of quality vegetable seed in Kenya | 2003–2005 | Kenya | |
| R8313 | Implementation of cocoa IPM in West Africa | 2003–2005 | Cameroon, Côte d'Ivoire, Ghana, Nigeria | 47 |
| R8314 | Quelea birds in southern Africa: protocols for environmental assessment of control and models for breeding forecasts | 2003–2005 | Botswana | 103 |
| R8315 | Establishment of satellite ICOSAMP systems and improved migrant pest reporting network | 2003–2005 | Southern Africa | 99 |
| R8316 | Bean root rot disease management in Uganda | 2003–2005 | Uganda | 34 |
| R8339 | Evaluation of the effects of plant diseases on the yield and nutritive value of crop residues used for peri-urban dairy production on the Deccan Plateau in India | 2003–2005 | India | 145 |
| R8341 | Promoting adoption of integrated pest management in vegetable production | 2003–2005 | Kenya | 122 |
| R8342 | Promotion of improved IPM practices for banana diseases and pests in Uganda | 2003–2005 | Uganda | 6 |
| R8349 | Developing crop protection research promotional strategies for semi-arid East Africa | 2003–2005 | Kenya, Tanzania | 66 |
| R8366 | Policy and strategy for increasing income and food security for poor farmers in Nepal and South Asia through improved crop management of high-yielding chickpea in rice fallows | 2004–2005 | Nepal | 155 |
| R8367 | Promoting farmer adoption and policy change for rice and vegetable pest pheromones in Bangladesh | 2004–2005 | Bangladesh | 169 |

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