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SCI Symposium

Closing the Yield Gap

Crop Protection for Poverty Alleviation

Chairmen: Dr Charlie Riches
NRI, University of Greenwich, UK
and
Professor Graham Matthews
IPARC Imperial College Silwood Park, Ascot, UK

Session Organisers: Dr Leonard Copping
Consultant, Saffron Walden, UK
and
Alan Knowles
FORM-AK, Tonbridge, UK
and
Professor Graham Matthews
IPARC Imperial College Silwood Park, Ascot, UK
and
Dr Charlie Riches
NRI, University of Greenwich, UK

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Food security in Africa: public-private partnerships for closing the yield gap

M Bokanga
African Agricultural Technology Foundation, PO Box 30709, Nairobi 00100, Kenya
Email: m.bokanga@aatf-africa.org

E Terry
Consultant, 4109 17th St. NW, Washington, DC 20011, USA

For the past 30 years, food availability in Africa has failed to meet the demands of a rapidly increasing population. The number of malnourished people has grown from 88 million in 1970 to 200 million in 2000 and the trend is projected to continue. While many causes have been identified for this alarming situation, limited innovation in African agricultural systems is one of the most significant underlying factors. A very large number of farmers are still using varieties inherited from their grandparents; the use of fertilizers is extremely low (about one tenth of the world average); pest and diseases have increased in severity while drought and the absence of irrigation take an increasingly frequent toll on crops that survive other biotic and abiotic challenges. The end result is that Africa has the lowest crop yields amongst all regions of the world, and these have barely increased in the past 40 years. African farmers feed the ever increasing population by expanding the land under cultivation rather than by increasing their productivity per unit of land and labor. This approach is damaging to the environment and is not sustainable because the amount of arable land is very limited.

Increasingly, African governments and regional organizations are recognizing the centrality of agriculture in the economic development of the continent. At their 2003 summit, African Heads of States committed themselves to allocating 10% or their countries' GDP to agricultural development. The Comprehensive African Agricultural Development Program (CAADP) developed by the New Partnership for African Development (NEPAD) calls for a minimum 6% annual growth in agricultural productivity to ensure that Africa meets its development targets.

While yields of most crops in Africa are the lowest in the world, African research institutes have over the years been developing high yielding varieties and soil fertility management techniques that can increase crop yields, sometimes by several fold. There is a significant gap between crop performance and the yields obtained on research plots and those achieved by African farmers. How can this gap be bridged?

In the late 1960s and early 1970s when international agricultural research centers (IARCs) were established, their mission was to use the best scientific talent to seek technological solutions to problems of agriculture in the developing world. It was assumed that national research institutions and extension services would take up and disseminate the findings from IARCs. While this model has been credited with the advent of the *Green Revolution* in Asia and Latin America, it has not worked for Africa. A new model is therefore needed. Although the public sector has not been efficient in distributing seeds, agricultural inputs and best agronomic practices to farming communities, the private sector has been very successfully at distributing Coca-Cola drinks and more recently cell phones to these same communities. Unfortunately, in many African countries, seed regulations and other policies have discouraged the private sector from distributing agricultural inputs. In recent years, however, some countries have introduced and enforced plant breeders' rights and have liberalized the seed sector. In response to this policy change, private sector investment in the seed industry is growing with the participation of both local and foreign investors.

For the foreseeable future however, the capacity to develop technologies and products for African farming conditions will rest with either national and/or international public research institutions (such as IARCs). Private enterprises, on the other hand, will continue to demonstrate an unchallenged ability to distribute products across rural Africa. Harnessing possible synergies to be derived from the capacities and capabilities of the public and private sectors presents a unique opportunity to bring to African smallholder farmers the inputs and knowledge they need to increase agricultural productivity.

The African Agricultural Technology Foundation (AATF) was created four years ago to access proprietary technologies (from within and outside Africa) and to put them in the hands of African smallholder farmers, after adaptation by public research institutes, on-farm testing by NGOs, research institutes and extension services, and dissemination by private entrepreneurs, stockists and agro-dealers.

A good example of this model is the dissemination of Imazapyr-resistant (IR) maize varieties to control *Striga* in maize fields, first in West Kenya, and now in Uganda, Malawi and Tanzania. BASF, a German multinational corporation owns the IR maize germplasm and has made it available to CIMMYT which bred the trait into varieties adapted to eastern and southern Africa. BASF also manufactures and distributes the herbicide imazapyr and had it registered for use in Kenya. The Weizmann Institute of Israel contributed the technology to coat maize seeds with imazapyr. Three Kenyan seed companies obtained breeder's seed from CIMMYT and multiplied it for large scale on-farm testing and field demonstration by NGOs, seed companies and extension services. Over 13,000 farmers were involved in testing the technology. Pictorial brochures, rural radios and newspapers were used by NGOs to reach many more farmers than those involved in field trials. The new maize variety produces high yields in farmers' fields where maize production was no longer possible due to severe *Striga* infestation. Today, this variety is commercially available to farmers in West Kenya, through a local seed company's network of dealers and stockists and through NGOs acting as middlemen. While the research institutes were instrumental in developing the technology, these would not have reached so many farmers so quickly without private sector involvement.

AATF aims to facilitate *agricultural innovation platforms* whereby various institutions are brought together so each can provide timely inputs to the agricultural technology value chain. Public and private organisations play clear roles, from basic research to applied research, field testing and commercialization, including facilitating market access to encourage farmers to produce a surplus. Keeping all the partners engaged in the process is the single most important challenge to bringing technologies to farmers. This model also provides, in our opinion, an efficient approach to ensuring that African farmers will benefit in the future from the products of gene technologies. It makes it possible to address, in an effective manner, issues such as intellectual property management, regulatory compliance and public awareness management for which traditional public research institutes and extension services do not have the comparative advantage.

Closing the yield gap: crop protection for poverty alleviation. Can we help? Should we help?

A Bennett
Syngenta Foundation for Sustainable Agriculture, Postfach, Basel CH-4002, Switzerland
Email: andrew.bennett@syngenta.com

The 2006 FAO report on the 'State of World Food Insecurity' (http://www.fao.org/sof/sofi/index_en.htm) tells that we are not on course to meeting the Millennium Development Goal on reducing poverty and hunger. However, this is not because of overall production in the world but a problem of access and availability – poor people are hungry and malnourished, the well-off are obese!

The Millennium Ecosystem Assessment, published by the Island Press in 2006 (http://www.millenniumassessment.org/en/index.aspx) concluded that although agriculture has been very successful in meeting the growing needs of society for food and the other agricultural products, current production systems and land-use practices have damaged many of the world's ecosystems.

Many recent studies predict that the demand for food, agricultural commodities and ecosystem services will increase and could double over the next generation. This demand will be driven by population growth, income increases, urbanisation, regulation, education and global trade.

World leaders are looking to agriculture to reduce poverty, support economic growth, provide worthwhile employment, conserve environments and provide an increasing diversity of environmental services.

Climate change and the rising demand for biofuels have added new challenges and opportunities for agriculture and landscape management.

Consumer concerns and changes in the structure of the agricultural industry are creating increased interest in and scrutiny of the sources and the methods of production used. Farmers are aging and it is increasingly difficult to retain the interest of young people in agriculture as a job.

Since agriculture began there are have been several approaches to enhancing yields – specialised and protected fields; fire; rotations, shifting cultivation and transhumance; better cultivation techniques; irrigation; seed selection; planting in rows; manures and chemical fertiliser; mechanical, biological and chemical crop protection; systematic breeding and genetic engineering. Seldom has a single technology survived for ever and it has been necessary to combine and integrate technologies to cope with rising demands and the capacity of pests and diseases to evolve, mutate or change their behaviour to exploit new opportunities. Bugs get up earlier, breed faster and go to bed later. Their capacity to adapt is a measure of their success and essential to their survival.

These challenges are huge and point in the direction that 'business as usual' or 'more of the same' will not provide sustainable solutions. Innovation and partnerships are needed, but from where will these new ideas and alliances come. Can we help?

There have been numerous studies comparing farmers' field yields with those that are attainable under experimental conditions. The great majority of these studies show that the yields obtained under field conditions are significantly lower. In Africa, the yields of food grains remain obstinately at around one tonne per hectare. Is this a problem of the statistics or are there real barriers to increasing yields?

Some of these studies imply that the technologies available are inappropriate, because they are reliant on unavailable or unaffordable inputs, such as water, credit, fertiliser and pesticides. Others point to a failure of markets, infrastructure, policies, governance or institutions. Others blame environmental factor such as climate change. Many advocate a greater emphasis being given to participatory approaches. Sadly the blame game seems more attractive that the solutions business.

Recent initiatives by Sasakawa, the Millennium Project, Rockefeller and the Gates Foundation have aimed to remove the technology and finance constraints through improved access and advice. They work primarily through the public sector or civil society. They have demonstrated that it is possible to increase yields dramatically – but are these approaches sustainable? Can they be replicated or sustained when the exotic inputs are no longer available – probably not!

It is noticeable that where markets are strong agriculture prospers. However, seasonal fluctuations in the yields from rain-fed agriculture are inevitable.

The Syngenta Foundation's experience has been that one of the main areas of failure has been in access to markets and an absence of small and medium businesses (SMEs) in the rural/urban interface. It is interesting to note that SMEs are responsible for creating a significant proportion of new jobs. However, the greater portion of development assistance is still focused on public sector spending which can encourage the public sector and civil society to engage where it might be more appropriate and sustainable for the private sector to take the lead. But stimulating the private sector requires more thoughtful, analytical and business-like approaches, as well as a commitment to longer time horizons.

Should we help? This raises both practical and ethical issues! By attempting to help are we creating cultures of dependency or pushing inappropriate technologies or approaches? Are we going for simplistic quick fixes when we should be placing greater emphasis on building indigenous capacity – particularly in the private sector? Sadly the development community interested in agricultural development has created a battle ground of ideologies – technofix v. technophobia; small v large; markets v subsidy; public v private goods etc. These ideological disputes do not help and in some cases have reduced investment and hindered the building of partnerships between players in the public and private sectors. We need fora to discuss and resolve these differences.

In conclusion – yes, the international development and scientific community can help but will only do so if we have done sufficient analyses and are prepared to invest adequately to build appropriate and robust indigenous institutions. There are no quick fixes. We must take a longer-term approach.

How relevant is crop protection research to poverty alleviation?

F Kimmins
Natural Resources International, Park House, Bradbourne Lane, Aylesford, Kent, ME20 6SN, UK
Email: f.kimmins@nrint.co.uk

The estimated rates of return of agricultural research and extension investment, including the development and application of crop protection technologies, are high across countries and commodities and have not declined over time. Some impressive examples have been recorded, for example, in West Africa, where cassava green mite biological control was first achieved, economic returns have reached a hundred fold – US $ 100 in return for each US $ 1 invested in the program (Dixon *et al.* 2003). The growing body of evidence on rates of return should encourage policy makers to invest significantly in the sector, but trends over the last two decades suggest otherwise. Investment in agricultural research and extension is still growing, but only at a decreasing rate (Pardey *et al.*, 2006). In many developed countries, investment has stalled and has become a small proportion in total science and technology spending while in many developing countries, investments are stagnating.

The lack of research and extension investment in many countries of sub-Saharan Africa and S. Asia is of particular concern because the livelihoods of 40-75% of the workforce in these regions are dependent on renewable natural resources including forestry and fisheries. There are a number of reasons for this declining support. Firstly, over four decades there have been significant changes in aid modalities such as the movement away from the green revolution technologies of the 1960s to 1980s and the integrated rural development projects of the 1980s and 1990s, to sector-wide approaches and support to poverty reduction strategies (PRS). Agriculture is featured in many PRS, but investment by national governments is low. Secondly, the international development agenda has focused on targets such as the Millennium Development Goals which, quite rightly, emphasise social sectors such as education and health, but do not mention at all productive sectors such as agriculture which provide opportunities for the poor. Thirdly, international and regional trade agreements and policies fail to support small scale producers and labourers. Finally, the evidence has not convinced policy makers that investment in agricultural research can tackle the multi-dimensional nature of poverty including the lack of equity and voice.

Some of these issues were explored during the implementation of the DFID Renewable Natural Resources Research Strategy between 1995 and 2006. DFID invested over £200 million in the RNRRS, funding over 1600 projects throughout sub-Saharan Africa (56%), South Asia (32%) and Bolivia (12%). The 10 programmes separately addressed crop production and protection, post harvest issues, market access, forestry, fisheries management, aquaculture, soil and water conservation, livestock production and animal health. All focused on improving the livelihoods of the poor through better management of natural resources and by developing new ways of working with and for this constituency. Multidisciplinary research between natural and social scientists became the norm, research initiatives usually included the requirements of stakeholders in the R&D agenda and used new promotional channels to enhance rural and urban livelihoods directly or indirectly.

The Crop Protection Programme (CPP) generated knowledge to improve pest, disease and weed management in systems that are managed by or employ the poor. Activities took place in over 20 countries and new partnerships, including those with NGOs and private sector, grew as the strategy evolved. Unfortunately, impact evidence such as that presented for the cassava mealy bug example does not exist from the RNRRS, but an independent evaluation found that the high quality of research had made significant contributions to scientific knowledge (Spencer *et al.*, 2005). There was clear evidence of positive impacts on the livelihoods of the poor in target developing countries as well as good potential for wider impact on poverty. Some of most valuable CPP lessons stemmed from the participatory processes which attempted to empower and increase the voice of poor communities, the development of new partnerships between researchers and users to improve uptake and the use of new communication channels and policy messages to create livelihood opportunities and benefits, directly or indirectly. Examples from CPP include:

- *Promotion of bean IPM strategies in E and S Africa 1997-2006. (Ward* et al., *in press)*
- *Understanding farmers demands from research in Bolivia (Bentley* et al., *2007)*
- *Policy change in E. African biocontrol legislation (Wabule* et al., *2003)*
- *Cost effective weed management practices for rice systems in S. Asia (Johnson* et al., *2003) Chickpea IPM in Nepal and Potato and groundnut IPM in Uganda*

The contribution of science to pro-poor growth is being increasingly recognised. DFID is doubling investment for agriculture, fisheries and forestry research in poor countries to £80 million a year by 2010 and its programme 'Research into Use' aims to put the best of the RNRRS into use across Africa and South Asia. A third of the budget is allocated to monitoring, impact and learning so this initiative will not only scale out research, but will identify essential actors in agricultural innovation systems, will explore the flow of information between the actors and how and why research is taken up or dropped. It should also capture qualitative as well as quantitative impacts of research. Lessons will inform managers and policy makers when considering future agricultural research investments.

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The benefits of rational pest control practices in Indian cotton

D A Russell
Natural Resources Institute, Univ. Greenwich, Chatham Maritime, Kent, ME4 4TB, UK
Email: d.a.russell@gre.ac.uk

K R Kranthi
Central Institute for Cotton Research, Wardha Road, Nagpur, India

In the late 1990s, some 40% of the variable costs of cotton production in Asia were for control of key pests, in particular caterpillars of the cotton bollworm, *Helicoverpa armigera*. Insecticide resistance, particularly to pyrethroids, was a major cause of the large and growing overuse of chemical pesticides. A series of research programmes from 1992 to 2005, supported initially by the Indian Council for Agricultural Research (ICAR) and the UK Dept. for International Development (DFID), later with support from the Common Fund for Commodities (CFC) and the International Insecticide Resistance Action Committee (IRAC), undertook detailed examinations of the genetic and biochemical bases of these resistances to the four common groups of chemistry used in the region (endosulfan, organophosphates, carbamates and pyrethroids.) (Kranthi *et al.* 2001a and b). Table 1 summarises the findings of this work.

Table 1. Distribution of resistance mechanisms in Asian *H. armigera*

	Metabolic				Target site		Penetration reduction
Mechanism	Oxidases	Esterases	GST	Ache	Nerve Insens	rdl	
Chemicals affected	Pyre.	OP/carb endo/pyre. h.	Pyre.	OP/ carb	Pyre.	End	Pyrethroid (others?)
India	***	**	*	*	**	*	?
China	***	**	*	*	*	*	*
Pakistan	**	**	*	*	*	*	*

GST – Glutathione-S-transferases; Ache – Acetylcholine esterase; rdl – dieldrin resistance mutation

Study of the cross resistance patterns relevant to these mechanisms gave potential rotation groups for use in reducing the impact of insecticide resistance in *H. armigera* control. Taking into account the need to control other pests, a 'window' strategy was adopted and trialled on an increasing scale to 1999 when 255 farmers in three states were using the methodology (Russell *et al* 2000). The Indian Council for Agricultural Research then adopted the practices in a series of programmes from 2000-2002 when a much larger, national programme was set up under funding from the Cotton Technology Mission funds. Simultaneously, the research base was strengthened and the programme rolled out into India and Pakistan with funding from the Common Fund for Commodities (2002-2005).

Working within a full IPM context and with the support of field staff in each village and a resistance monitoring laboratory in each district, the insecticide rotation programme shown in Table 2 was implemented (with minor regional variations) across all 11 cotton states in the 26 cotton growing districts where insecticide use was the biggest concern (Kranthi *et al.* 2005). Results have been spectacular. Table 3 shows the increasing scale of operations from 2004-2007, with close to 90,000 growers now actively enrolled in the programme in over 1,000 villages spread across India.

Table 2. Simplified IRM programme recommendations for Central India 2002-5

Sucking pests	Bollworm window 1	Bollworm window 2	Bollworm Window 3	Bollworm window 4
0 - 60 days* Zero sprays	60-90 days endosulfan (neem/HaNPV)	90-105 days spinosad/ indoxacarb	105-120 days organophosphate / carbamate	120-140 days pyrethroid

Note: Windows 2 and 3 are commonly run together, using only OP/carbamates, by resource-poor growers.

Figures are weighted averages of the 11 state averages and compare results with neighbouring villages which are not in the programme. Average insecticide use reductions, yield increases and increased net profit were seen in all 11 participating states.

Table 3. Recent progress in the IRM village programme

	No of villages	No of farmers	% reduction of sprays	% Yield increase	Net profit increase $US/ha	Total benefit to farmers	Benefit to cost ratio
2004-5	444	20,525	-46%	11%	$193	$11.5 mill	28:1
2005-6	565	46,400	-48%	12%	$183	$24.6 mill	32:1
2006-7	1,023	89,000	-52%	10-15%	$174	$33 mill	44:1

Insecticide use continues to be approximately halved, while significant yield increases contribute to the $US170-200/ha average profit increase, more than doubling cotton profitability for these farmers. The Indian government is committed to expanding this programme in the current five year plan to 2011, having attained a >40:1 benefit to cost ratio for the programme with expenditure of less than $US4/ha. Insecticide resistance to all four classes of chemistry has fallen in the programme areas and more widely as the success of the programme has been publicised though village level plays, >1,000 farmer meetings, broadcasts, newspapers and extension systems. The use of these older chemistries is now falling nationally with only modest increases in the use of newer chemicals e.g. spinosad and indoxacarb. This programme contributed to the sharp increase in national cotton production from 15 million bales in 2002 to over 25 million bales in 2006, starting well before any significant impact from the planting of Bt cotton. The programme team, led from the Central Institute for Cotton Research in Nagpur, won the 2006 ICAR Award for Team Science.

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Semiochemicals – the future for crop health

A Cork
Natural Resources Institute, University of Greenwich, Chatham Maritime, Kent ME4 4TB, UK
Email: a.cork@gre.ac.uk

P L Rau
AG Bio Systems Pvt. Ltd, 61 Chandragiri Colony, Secunderabad 560 015, India

Semiochemical-mediated communication affects a myriad of interactions between organisms. The best studied and most commercially exploited are pheromones and kairomones. Employed to manipulate the behaviour of economically important pest species, technologies have been developed to monitor and control populations that impact on crops providing the basis for a global $150 million per annum industry. Yet semiochemicals are by no means restricted to moderating interactions within and between species and their hosts, but also act at a tritrophic level enabling, for example, plants to alert parasitoids to the presence of herbivorous insects. The distinction between hormones and semiochemicals has become blurred with the isolation of a phytohormone, jasmonic acid, in insect eggs and demonstration of gravid female moths modifying their behaviour in response to phytoecdysteroids.

In principle, this knowledge and associated technology can be utilized to alleviate the poverty of resource-poor farmers in threshold countries. Indeed early success was achieved in Egypt with the female sex pheromone of the pink bollworm, *Pectinophora gossypiella*, being controlled by mating disruption. By 1997, almost the entire 400,000 ha crop was treated with pheromone, saving between $5.1 and $9.5 million per annum and reducing national insecticide consumption by 40%. In India, cotton sustains the livelihoods of 60 million people and accounts for 20% of Indian exports. The pest complex is quite different from Egypt, with *Helicoverpa armigera* being the main pest species and not amenable to control by mating disruption. Yet IPM is promoted through the Government sponsored 'Technology Mission on Cotton'. Introduced in 2000, the Mission provides a mechanism for Government tenders to procure pheromone traps and lures for use by cotton farmers; accounting for 90% of the two million sold in India. This initiative has seen improvements in quality and yields almost doubled to over 500 kg/ha. However, since 2002 the area under *Bt* cotton officially increased from 0.03 m ha to 1.6 m ha in 2005, 18% of the total crop area and in some states unofficially estimated to account for over 90%.

The economic importance of Government tenders to SMEs and their dependence on pheromone blend importers has stifled competition. Tenders are price and not quality sensitive, resulting in farmers receiving poor quality products that undermine the IPM message promoted by NGOs and extension functionaries. Others question the motives of SMEs and espouse the virtues of empowering farmers to use home-produced crop management solutions. Nevertheless, without an efficient private sector to produce and promote environmentally-acceptable, cost-effective and sustainable crop protection technologies in threshold countries, technology transfer will not be sustained and opportunities to alleviate poverty lost. SMEs, by their nature, are innovative and flexible, but lack access to knowledge and finance. Increased interest in pesticide-free crop produce has encouraged SMEs to develop and promote packages of technologies for control of key crop pests and diseases. This process has been greatly assisted by donor funds made available to support the development and promotion of semiochemical technologies such as lure-and-kill for control of fruitfly, *Bactrocera cucurbitae* and mass trapping for eggplant fruit and shoot borer, *Leucinodes orbonalis*; pests of critical economic importance to vegetable producers in the sub-continent. Control of the latter pest can account for up to 40% of production costs, $1,200/ha/annum in Bangladesh. Mass trapping is promoted as part of a package including the egg parasitoid, *Bracon hebetor*, and use of grafted plants with root stock resistant to bacterial wilt. To compliment these initiatives, donor-funded technical assistance was provided to companies in South Asia to improve the efficacy of their technology enabling several to develop new products for control of palm weevils, sugarcane borers and coffee white stem borer, *Xylotrechus quadripes*.

In related work, considerable efforts were expended to control the yellow rice stem borer, *Scirpophaga incertulas*, by mating disruption in India, and while efficacious the technology was not cost-effective. In contrast, mass trapping of *S. incertulas* proved to be both efficacious and cost-effective, but is only slowly being adopted in the absence of external support. Current efforts are focused on development of auto-confusion which holds considerable promise as an environmentally-acceptable alternative to insecticides. Formulated in a biodegradable wax the technology is hand-applied without the need for expensive spray equipment. The fact that auto-confusion does not require traps or water for application suggests it would be appropriate for use by resource-poor farmers in semi-arid crops such as millet, sorghum, pigeonpea, groundnut and maize.

In South America, pheromones are used on large acreages for control of tomato pinworm, *Keiferia lycosicella* allowing growers to earn an additional $3,500/ha compared to those who use conventional insecticides. Codling moth, *Cydia pomonella* is controlled by pheromones in apples on an estimated 100,000 ha worldwide, with 10,000 ha in South America and 14,000 ha in South Africa. Aggregation pheromones of Coleoptera have also been exploited by resource-poor farmers to control cotton bollworm, *Anthonomus grandis* in South America, with over 350,000 ha treated in Colombia, Paraguay, Brazil, Bolivia and Argentina, reducing populations by 85% and damage typically from 40% to a minimal level. Similarly, sweet potato weevil, *Cylas formicarius* is controlled by sex pheromone traps as part of an IPM programme in Cuba on an area of 35,000 ha, eliminating the need for between 12 to 15 applications of organophosphates used previously.

Many of the pheromones of economically important African crop pests have been identified and yet their impact at the farmer level has been disappointing. In South America and South Asia, semiochemicals compete with insecticides in the market-place, and while it is important to understand the issues that motivate farmers' choices of crop protection, they are primarily driven by economics and availability, as exemplified by the rapid adoption of *Bt* cotton in India. For resource-poor farmers in sub-Saharan Africa to benefit from semiochemicals in crop protection it will require the creation of an enabling framework that can deliver quality products in the absence of donor finance and in the face of competition from conventional crop protection technologies. SMEs are best placed to manufacture and market this technology but they will inevitably focus on farmers producing high value, export oriented crops. As in South Asia, semiochemicals are best introduced as part of technology packages that eliminate the need for pesticides, but to develop and validate these strategies has cost implications that will inevitably be dependent on increasingly scarce donor finance.

Biological pesticides for Africa: why has so little research led to new products to help Africa's poor?

D Grzywacz, A J Cherry
Natural Resources Institute, University of Greenwich, Chatham, Kent, ME4 4TB, UK
Email: d.grzywacz@gre.ac.uk

R Gwynn
Rationale Biopesticide Consultants, Bagmoors Cottage, Pettinain, Lanark ML11 8SR, UK

For many years there has been a sizeable body of research focused on developing biological control agents (BCA) for use in Africa. Microbial entomopathogens, such as bacteria, viruses, fungi and nematodes, have been seen as the source of new crop protection products to tackle the myriad pests and diseases that contribute so much to limiting yields in the less developed countries, particularly in Africa. However, much of the research effort has failed to lead to new products or had any direct impact on the ground. This raises serious questions: what are the issues and factors that have impeded the research from being brought into use. Recently there have been a number of public sector led initiatives to promote biological pesticides. Study of these cases can provide much information about the issues that may be impeding the development of these agents.

The focus on BCAs as crop protection solutions in Africa has a number of diverse drivers. There is the perception that these agents are 'natural' and safer than synthetic chemical products, this has been a major plus for some funders, but its evidential basis is questionable and as a force for driving farmer adoption of BCAs it is weak. A significant sector of the research and development community seems ideologically opposed to the use of chemical pesticides, or indeed any commercially sourced synthetic agro-inputs, and promoting BCAs can reflect this agenda. Thus, major drivers of research into the development of BCAs have not necessarily selected them because they are the 'most fit for purpose' in tackling specific crop problems or because meet genuine farmer needs. A more realistic approach would be for projects to include stronger end user input in the process of selecting, developing and implementing BCA projects.

The limited R&D capacity for BCAs in Africa is also a serious constraint. International research centres and collaborative north-south projects have helped by augmenting the very limited local capacity in the research stages. However, without an indigenous industrial expertise in scaling-up, in production and in commercialization, the research efforts frequently progress no further than promising small scale field trials. Commercialization of BCAs needs industry involvement for their expertise in product development with a rationale use of resources. To achieve this however the cultural differences between research and commercial organisations need to be bridged with new ways of working and trust developed. Issues such as unrealistic valuation of intellectual property rights have tended to inhibit development of good relationships.

Historically, failure to recognize the health drawbacks of the indiscriminate use of pesticide on food crops has restrained demand for safer production that might create the market for BCAs. Recent concerns about safety for the consumer and the environment have driven commercial growers to adopt an Integrated Pest Management (IPM) approach to crop protection. BCA can be successfully incorporated into IPM systems where farmers have adequate knowledge, resources and supply systems, but apart from in the intensive high value horticultural 'hot spots' in Kenya and South Africa, most African farmers lack the expertise, resources or infrastructure into which BCAs can fit. The high cost of BCAs can be a very significant factor for most farmers in Africa. The majority can only afford the minimum of inputs, and broad spectrum chemicals are for them a far more appropriate solution than pest-specific BCAs. BCAs have the advantage that they can be produced locally, perhaps at lower cost, by a range of methods each requiring different economic and technical resourcing. To implement the appropriate approach successfully, however, engagement by researchers with policy makers and industry is vital. There is considered to be potential for some BCAs to be produced at village level with a relatively simple technological base; an attraction for some NGOs who see this as a means to empower resource poor farmers. However, issues of registration, quality control and economics in particular mean that this model is far from proven as a sustainable model of large-scale delivery.

Market size and value is a key consideration in developing new commercial biopesticides. The African market is small in world terms and highly fragmented. In China and India, development of new BCAs has been rapid in recent years, but they represent two extremely large and diverse markets providing many product niches within a single registration system. Market size has important implications in registration; efforts are now underway to simplify, harmonise and standardize registration of BCAs in Africa, but the need to register in multiple countries through systems that lacked expertise in BCAs has been a significant deterrent to many initiatives. Another constraint has been the attitude of some regulatory agencies that perceive bio-security problems in the importation of exotic BCA, even from neighbouring countries sharing identical, even contiguous pest-crop systems. This in turn has reflected an absence of any coherent government policy to promote BCA use or production. Lack of awareness of BCAs by policy makers and opinion formers means there has been little policy action to support the research. Research funders have until recently failed to address this, but there are now some examples of capacity building: DFID and the COLEACP Pesticide Initiative Programme have provided capacity building expertise in Kenya for BCA registration, mass production and commercial development.

Given these weaknesses in market and infrastructure, it would make sense to focus efforts where the pest-crop system are least challenging for BCAs. The high value export horticulture sector is one where higher farmer resources and familiarity with IPM make it promising. It is also here that MRL legislation and consumer preference for 'low pesticide produce' might provide the market driver for their adoption, and indeed Kenya and South Africa have been a focus BCA research. Another promising entry point for BCAs is control of migratory pests such as locust and armyworm where outbreaks can involve environmentally sensitive national parks. Here national or regional co-ordination of control programmes may ensure both a sizable market and sufficient expertise to use BCAs successfully.

In conclusion, the relatively slow progress in promoting the use and adoption of BCA in Africa is the product of many factors beyond the simple issues of product effectiveness or suitability. Successful development of BPs to meet Africa's needs lie in focusing efforts on the best fit cases where the situation is already favourable. Then, through the development of a few successful products this process may in itself build new capacity and embed approaches that will facilitate further developments.

The protection of farmers' health is key to ensuring optimal agricultural production

P M Ndumbe
Faculty of Health Sciences, University of Buea, PO Box 63, Buea, Cameroon
Email: pndumbe@yahoo.com

A Same-Ekobo
Faculty of Medicine, University of Douala, Cameroon

P B Nkot
The Yaounde Initiative Foundation, Messa, Yaounde, Cameroon

Background

The promotion of agriculture in the medium and least developed countries is a potent means of helping to address extreme poverty in its many dimensions (income poverty, hunger, disease among others) as spelled out in the UN Millennium Declaration. The declaration, signed in September 2000, commits the 192 UN member states to achieving eight goals. The success of initiatives aimed at promoting agriculture is contingent on the promotion of health of the farmers. Among the diseases endemic in Cameroon's rich forest and savannah regions are vector borne diseases. The most notorious of these are malaria and filariasis. We present data obtained from two regions of Cameroon where agriculture is predominant.

Methods

This study was carried out in the Sanaga Maritime division (Littoral province) and Fako division (South West province) of Cameroon. We visited five villages in the first and seven in the second. We sought to find out from the villagers what they considered to be the greatest impediment to their agricultural endeavours. We equally inquired from the health services and the villagers what they considered to be their common health problems. In the Sanaga Maritime division, we proceeded to test blood samples and skin snips from selected consenting subjects in order to look for the presence of malaria parasites and *Loa loa* microfilariae (from blood) and *Onchocerca volvulus* microfilariae (from the skin snips). These studies were approved by the faculty's Ethics Committee.

Findings

In the two divisions studied, the over-riding impediment to successful farming was ill-health. This was closely followed by the presence of insects. With regard to ill-health, malaria was the number one culprit. Among the insects incriminated as impediments to successful farming were mosquitoes.

However, another common nuisance is the *Simulium damnosum* (black fly), vector for onchocerciasis (river blindness). Thus, farmers were unable to farm either because they were ill from malaria or onchocerciasis or because of the nuisance caused by the biting insects. There were 428 persons who consented to being examined. Of these 21% had *Plasmodium falciparum* in their blood, 51% had *O. volvulus* microfilariae in their skin and 5% had *L. loa* microfilariae in their blood.

Discussion

Our study has highlighted two issues that we need to address as we engage in the promotion of agriculture within the context of alleviating poverty and disease through wealth creation and the increase of food production to address issues of malnutrition and famine in a continent laden with natural and man-made disasters. First, we need to address the issue of vector control. Vectors, such as mosquitoes and black flies are a nuisance for farmers.

They hum and drone close to the ears of farmers and bite them in their exposed parts. Whole villages have been known to vacate arable land because of the presence of vectors. These vectors also transmit disease causing agents: plasmodia which cause malaria and microfilariae which may result in blindness. Although malaria generally tends to make adults sick and therefore take time off work, it is a leading cause of deaths in children and of abortions in pregnant women. Further, sick children need to be looked after, thereby reducing the number of hands available for field work. In certain farm areas where irrigation is used such as in rice fields in the savannah regions, the use of cattle as a bait to divert mosquitoes away from humans is being investigated.

The second issue which arises from this study is the reinforcement of the underlying relationship between health and development. Agriculture in most of Africa is practiced by the poor. They tend to be particularly vulnerable to all kinds of prevailing diseases, but have a chronic problem of access to health care. Agricultural development or extension programmes must look into integrating health promotive, preventative and curative activities within their packages.

In Cameroon, the Yaounde Initiative Foundation (YIF) has started a programme aimed at improving the livelihoods of people along the Sanaga river valley by implementing integrated vector management. Vector Intervention Teams (VIT) will be responsible for vector management within their villages for both the anopheline mosquitoes and the black flies. The fact that they will be using insecticides for their work in mosquito control (insecticide treated nets, ITN, and indoor residual spraying, IRS) will raise issues of development of resistance to these insecticides.

Within the context of its social obligations to communities, the Faculty of Health Sciences of the University of Buea is working closely with the YIF to learn from their experiences and apply the positive lessons in its communities.

Weed management in Africa: experiences, challenges and opportunities

D Chikoye
International Institute of Tropical Agriculture, Avenue Eduardo Mondlane, No 326, Room 210, Girassol Office Center, Nampula, Mozambique
Email: d.chikoye@cgiar.org

J Ellis-Jones
Agriculture-4-Development, 4 Silbury Court, Silsoe, Beds, MK45 4RU, UK

C Riches
Natural Resources Institute, University of Greenwich, Chatham, Kent ME4 4TB, UK

L Kanyomeka
Crop Science Department, University of Namibia, Namibia

Weeds continue to undermine efforts to improve farm productivity in sub-Saharran Africa (SSA). Seven of the ten 'world's worst weeds' (*Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa crus-galli*, *E. colonum*, *Eleusine indica*, *Sorghum halepense* and *Imperata cylindrica*) are widely distributed in Africa (Holm et al. 1977). Other problem weeds include *Striga* spp., *Rottboellia cochinchinensis*, *Commelina* spp., and *Euphorbia heterophylla*. These are both competitive and difficult to control. For example *I. cylindrica* is ranked as the most troublesome weed in cassava, maize, and yams in West Africa. *C. dactylon* is serious weed of cereal crops in Southern Africa. *Echinochloa* spp are serious weeds of rice. *Striga* is a parasitic weed that thrives under conditions of low soil fertility. In West Africa, *I. cylindrica* competition caused an estimated 50% loss in cassava and 20-80% in maize. Upland rice yields with farmers' weed control methods were 44% lower than on researcher weeded plots. Losses from *Striga* can be 100%.

Weeding by hand hoeing is common in SSA, using 50 to 70% of the labour needed to grow a crop (Chikoye *et al.*, 2001). Smallholders are generally aware of the detrimental effects of weeds but delayed weeding is caused by labour shortages due to the migration of younger people to urban areas, while HIV/AIDS and malaria exacerbate labour bottlenecks by reducing labour productivity. Farmers, particularly women and children who provide over 50% of agricultural labour, would benefit greatly from low-cost, labour saving weed control practices. These must be matched to the socio-economic circumstances of communities if adoption is to be widespread. Herbicide use can be a pro-poor technology where labour is expensive and in short supply if products are sold in appropriate size packs, training on application is provided and there is a ready market for produce. Mechanization reduces the drudgery associated with manual weeding. To improve access to mechanization, greater focus is needed to design appropriate tools and implements requiring less energy; to promote ox-drawn implements, low horsepower tractors and to design more affordable sprayers.

Successful attempts to promote improved weed management in SSA include:

1) *Imperata* in West Africa: Participatory Research and Extension approaches were used to promote *I. cylindrica* management practices in Nigeria. Researchers and extension agents provided potential solutions (tillage practices, herbicides, cover crops and improved

agronomic practices) for farmer groups to evaluate. Trial monitoring and evaluation allowed farmers to share experiences and provide feedback to researchers. Labour use decreased by 54-96% as farmers switched from hoe weeding to chemical control in cassava, yams, or soybean. Chemical control reduced speargrass density by 88-97%, gave 38-55% higher crop yields and had a 28-50% lower cost than farmer control methods. Adoption depended on the availability of improved seed, fertilizers, herbicides, and output markets. The benefits of improved technologies included were increased incomes, reduced drudgery, improved food security and nutrition and improved soil fertility. These benefits accrued to women, young people, and the very poor, who often bear the brunt of weeding.

2) Wild rice in Tanzania: The perennial wild rice *Oryza longistaminata* and the annual *O. punctata* are constraints to lowland rice production in Tanzania. Because of the labour needed to manually remove wild rice from the rice crop farmers tend to avoid infested areas although these are on fertile soils with a good depth of water. Pre-planting applications of glyphosate to reduce wild rice populations have enabled farmers to sow their crop after one plough pass instead of two, to reduce labour for in-crop weed control by 50% and increase average yield by 65%. As there is a ready market for rice, farmers view glyphosate use as highly profitable particularly as herbicide use allows them to plant a recently introduced high yielding rice cultivar that has a "short straw" type that is not competitive with weeds.

3) Tillage for cotton in Uganda: Farmers plough twice to prepare land for cotton in NE Uganda. Timely tillage and planting is difficult for households who do not own draught animals and need to borrow a plough team. By killing weed re-growth with glyphosate after only one plough pass farmers can plant into a weed-free seed bed when soil moisture is optimum. Subsequent labour requirement for weeding the cotton crop is also reduced. Use of the herbicide is particularly effective where perennial grasses (*C. dactylon* and *I. cylindrica*) and sedges (*C. rotundus*) are a problem.

4) Animal-drawn weeders: Farmers in east and southern Africa use animal-drawn weeders because they reduce drudgery and save labour and time spent on weeding by 20-70% compared to hand-hoeing (Chatizwa and Vorage, 2000). Usage is being promoted through giving farmers loans to buy draught animals, training local fabricators and blacksmiths to service the weeders, training of agricultural extension officers and farmers, and encouraging farmers plant their crops in rows. Use of animal-drawn weeders has contributed to increased labour productivity, and increased education opportunities for among young people who often lose time for school due weeding activities.

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GM crops – their role in less developed countries

M Newell-McGloughlin
University of California Systemwide Biotechnology Research and Education Program (UCBREP), One Shields Ave, Davis, CA 95616, USA
Email: mmmcgloughlin@ucdavis.edu

Biotechnology has introduced a new dimension to agricultural innovation, offering efficient and cost-effective means to produce a diverse array of novel, value-added products and tools. It has the potential to improve qualitative and quantitative aspects of food, feed, fibre and biofuel production, reduce the dependency of agriculture on chemicals and fossil fuels, diminish over-cultivation and erosion, improve nutrition and functionality of foods and feeds and lower the cost of raw materials, all in an environmentally-sustainable manner. Agricultural biotechnology has helped farmers around the world boost their productivity and grow crops in more ecologically healthy fields while allowing much more efficient use of resources. This technology allows reduced tillage, which cuts down on greenhouse gas emissions, water runoff, machinery and fossil fuel use and soil erosion. Meanwhile, the benefits experienced by larger-scale farmers in both industrialized nations and lesser developed countries are already considerable. A recent study (Marvier *et al* 2007) indicates that biotech crops may contribute to increased productivity in sustainable agriculture. The study analyzes, for the first time, environmental impact data from field experiments all over the world, involving Bt corn and cotton. In an analysis of 42 field experiments, they found that Bt crops can have an environmental benefit because large-scale insecticide spraying can be avoided. Organisms such as ladybirds, earthworms, and bees in locales with 'Bt crops' fared better in field trials than those treated with insecticides.

An economic analysis (Brookes & Barfoot, 2005) shows that in the first nine years of GM crop cultivation, global net farm income increased by $27 billion; the environmental footprint associated with pesticide use was reduced by 14%; there was a reduction in carbon dioxide emissions in 2004 equivalent to taking nearly five million cars off the road for a year. Reduced-till agriculture means healthier soil, with reduced erosion and far less carbon dioxide release. In general, cultivation is not a sustainable practice. It is energy intensive, exposes soil to wind and water erosion. It allows rain to compact the soil, increases the oxygen content of the soil, allowing organic matter to oxidize away. In turn, lower organic matter in the soil allows more compaction and more nutrient loss. Pesticide use fell by over 170,000 tonnes. In 2004 alone this was over 40,000 tonnes, equivalent to more than 30% of total active ingredients used on crops. Less spraying means fewer tractor passes, contributing to lower CO_2 emissions. Insect resistant maize also has a collateral effect - less insect damage results in much less infection by fungal moulds which reduces mycotoxins that are known health risks causing such problems as liver cancer to humans and animals. The only 'natural' way to control those fungi is the use of copper sulfate which has one of the highest toxic hazard ratings of acceptable pesticides and selects for antibiotic resistant bacteria in the soil.

Green *et al* (2005) suggest that intensive high-yield farming on less land is better for wildlife than 'wildlife friendly' less efficient farming. They provide convincing evidence that without yield increase, land use will double by 2050 and that this effect will be especially significant in developing countries where, without greater productivity, China and India will need four times the land area to support their expanding populations. They show that in Latin America, where increased productivity was achieved, there was a significant decrease in deforestation; those producers with greatest yield increase had lower land use.

Of the 10.3 million farmers in 22 countries who grew biotech crops on 102 million hectares in 2006, 90% (9.3 million) were in developing countries (James, 2007). India, the largest cotton growing country in the world, registered the highest proportional increase with a gain that almost tripled its Bt cotton area to 3.8 million hectares. In China, use of genetically engineered cotton eliminated the use of 71 million kg of pesticides, an amount approximately equal to all of the pesticides used annually in California. In addition, because of the primitive method of back-pack applications, significant reduction in pesticide use literally saved lives. A World Health Organization (WHO, 2005) report noted that indirect benefits of agricultural biotechnology include reduction in chemical usage, enhanced farm income, crop sustainability and food security, particularly in developing countries. The report concludes that GMOs offers the potential of increased agricultural productivity and improved nutritional values that can contribute directly to enhancing human health and development. Agricultural research of all forms holds an important key to meeting LDC needs, the FAO said, adding that biotechnology can speed up conventional breeding programs and may offer solutions where conventional methods fail. That is good for growers, consumers, and anybody who cares about the environment.

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Emerging technologies for Striga control in Africa

G Ejeta
Purdue University, Dept of Agronomy, 915 W State St, West Lafayette, IN 47907, USA
Email: gejeta@purdue.edu

Introduction

The root-parasitic witchweeds (*Striga* spp.) remain a severe problem in semi-arid areas of sub-Saharan Africa infesting nearly 100 million hectares of maize, sorghum, pearl millet, cowpeas and upland rice. *Striga* is a poor farmer's problem as infested areas coincide with where the poor farm and hunger prevails (Ejeta, 2007). Farmers abandon lands heavily infested with *Striga*, leading to greater land pressure and exacerbating the natural resource crisis. Eradication and control of *Striga* have been formidable challenges and beyond the knowledge base and the economic reach of subsistence farmers. Decades of research has now generated a better understanding of the nature of the parasite and its association with its hosts, finding that have more recently led to the development of appropriate and cost effective practices for *Striga* control. Two control practices, validated by farmers and officially launched in eastern Africa for wide scale commercial application and adoption, are briefly described below.

Multi-genic *Striga* resistant cultivars

Significant gains have been made in breeding sorghum cultivars with multi-genic resistance to *Striga*. A paradigm was developed upon which the complex trait of *Striga* resistance was dissected into simpler components based on *Striga*'s interactive points with its hosts. This paradigm was based on the hypothesis that genetic variants could be found in nature or induced through mutagenesis for each of the key signals involved in successful parasitism. For each stage of the host/parasitic interaction, the particular signal involved was characterized, laboratory assays were developed, and genetic populations were evaluated using these assays to establish mode of inheritance, and to combine unique recombination. The assays were also useful to describe specific mechanisms of *Striga* resistance that were based on low germination stimulant (*lgs*) production, low haustorial factor (*lhf*) production, the hypersensistive response (*HR*), and the incompatible response (*IR*) induction following infection. Using this approach, sorghum germplasm with superior *Striga* resistance were identified. The inheritance of each of these sources were studied, molecular markers linked with genes for resistance were identified, and new sorghum cultivars were developed and released for wide cultivation in several countries. Adaptive tests were conducted in each country to assess agronomic merit of these cultivars. Three *Striga* resistant cultivars, P9401, P9403, and PSL85061 were recommended for commercial cultivation in Ethiopia under the local names of Gobiye, Abshir, and Brhan respectively.

In Tanzania, two other cultivars P9405 and P9406 were recommended for wide cultivation under the local names of Hakika and Wahi. Large scale adoption and diffusion of these cultivars as components of integrated *Striga* management (ISM) was facilitated by national programs and NGOs in Tanzania, Eritrea, and Ethiopia that encouraged entrepreneurial seed production, and linked farmers to markets. Where packaged along with soil moisture conservation and soil fertility management practices in an ISM program, these cultivars effectively suppressed *Striga* and dramatically increased sorghum grain yields after several years of testing. *Striga* count from the ISM package plots were 10 to 15 times lower, while sorghum yields were two to three times higher than plots planted to local cultivars. In

Ethiopia where the ISM technology was tested over four consecutive crop seasons (Tesso *et al.*, 2007), adoption was high with estimates of over 100, 000 families using the practice and increasing demand for seed. ISM was officially recommended and launched in early 2007 by the government of Ethiopia as an essential practice in *Striga* control in areas of the country where the parasite is endemic. In Tanzania, inclusion of the two cultivars in a well organized participatory regional ISM pilot test (Mbwaga *et al.*, 2007) with the use of animal manure and/or inorganic fertilizers planted in tied-ridges to ensure soil moisture conservation, gave effective control of *Striga* and increased sorghum yields significantly. Demand for seed of the new cultivars is increasing as farmers respond to market opportunities in the brewing and animal feed sectors.

Herbicide seed treatment of imidazolinone resistant maize

This technology, developed through the collaboration between the international maize and wheat research centre (CIMMYT), the Weizmann Institute of Science, and the company BASF, combines low doses of imazapyr (<30 g/ha) herbicide applied as a seed coating to non-transgenic Imidazolinone Resistant (IR) maize seed giving early *Striga* control before or during attachment to the maize roots. Kanampiu *et al*., (2007) reported that imazapyr can reduce the *Striga* seed bank by 80-100% in the 0-30 cm soil top layer. There are no effects on intercropped legumes, if they are sown at least 12 cm away from the treated maize seed. Since the herbicide can be added to a standard seed treatment, the extra cost of this technology is limited to the cost of the herbicide, estimated at about 4 US$/ha, which corresponds to an increase of 8% of the seed cost.

From 1996 to 2004, the herbicide resistance gene was bred into newly developed stress tolerant tropical maize varieties. During 2004, several new IR-maize open pollinated varieties (OPVs) were tested on-station and on-farm in several countries. Following proof of concept in the field, imazapyr was registered as a seed treatment by BASF and was trademarked as the 'Strigaway' technology. The technology and hybrid varieties were later extensively tested and received their first regulatory approval in Kenya, after results showed effective *Striga* control and significant increase of maize yields. The technology was commercially launched in Kenya in July 2005 after extensive pre-release demonstrations of the technology throughout western Kenya. The first new commercialized maize hybrid is marketed under the name of Ua Kayongo (*Strig*a killer). Six early OPVs, five late OPVs and two hybrids have also been allocated to seed companies and national programmes (NARS) for further testing and to generate data required by regulatory agencies for registration and commercialization. Wide scale participatory field testing of elite IR-maize material is also being carried out by NARS and seed companies in several African countries to encourage selection of varieties with specific adaptation and quality attributes for each respective country.

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Improving cocoa crop protection techniques for sustaining rural livelihoods in West Africa

R P Bateman
IPARC, Imperial College London, Silwood Park Campus, Ascot, Berks SL5 7PY, UK

M Gilmour
Mars Inc, Dundee Road, Slough, Berks, SL1 4JX, UK

K P Hebbar
Mars Inc / USDA-ARS, SPCL, Beltsville, 20705 MD, USA

Approximately 70% of the world's cocoa comes from West Africa, with small family farmers producing the vast majority of the world's supply. In this region, the most important disease is black pod (especially the invasive *Phytophthora megakarya*) and cocoa mirids (*Sahlbergella* & *Distantiella* spp.) are the most important insect pests. In addition, the need to manage cocoa swollen shoot virus has recently become more apparent in Ghana and Côte d'Ivoire. Mealybugs (*Planococcoides* spp.) are known to act as vectors, which in turn are tended by black ants, but the disease has proved difficult to control by conventional methods so emphasis has been placed on the development of resistant cocoa varieties.

In contrast, Integrated Pest Management (IPM) measures continue to be the principal method for managing black pod diseases and mirids. Current IPM strategies rely on cultural methods (especially sanitary harvesting) together with sporadic use of fungicides and insecticides. Furthermore, implementation of control techniques by smallholder farmers may be erratic and poorly performed. Farmers have limited access to finance to buy chemical inputs, and when they can, often prefer to apply cheaper, older compounds without appropriate or personal protective equipment (PPE).

Application practices may be inefficient in terms of dose transfer and untimely. When used too near to harvest or inappropriately in stores, pesticide residues may ensue which are, or will shortly be, subject to increased controls in Japan and the EU. The diminution of available active substances in Europe resulting from Directive 91/414/EEC is well known by the crop protection community, but the introduction of EC/396/2005 extends the reach of the former to residue tolerances of compounds for imported commodity crops such as cocoa.

Whereas it has been stated specifically that the purpose of the latter is not to create barriers to trade, it has raised concerns amongst producing countries and highlighted the need for:

(i) better agricultural practices;
(ii) enhancing research into substitutes for obsolete pest control methods.

Certain Farmer Field Schools have agreed that WHO/EPA Class I and II products are inappropriate for smallholder farmers with little access to PPE. With the development of a substantial number of new molecules since the 1980s it should now be possible to find alternatives to class I pesticides and the most toxic products in class II.

In response to this need, we describe recent research initiatives, supported by Cocoa Research UK, Mars Inc and the US Department of Agriculture, that provide better understanding of crop-pest interactions and the use of biology-based control agents as possible chemical substitutes that are cost-effective and safe to both farmers and consumers. Outputs include:

(1) Development of better screening methods and laboratory-to-field procedures for assessing conventional and more environmentally friendly techniques which are compatible with IPM practices.

(2) Introduction of more efficient, safer pesticide application practices. Two approaches to improving application seem appropriate:
   (i) optimised nozzle selection for manual hydraulic sprayers used by the majority of smallholders;
   (ii) better selection and use of motorised mistblowers for collaborative, commercial or centralised control operations (such as area-wide spraying of cocoa pests with approved fungicides and insecticides in Ghana by the National Cocoa Disease and Pest Control Committee: CODAPEC).

(3) Identification and proof of concept of biologically-based methods; these currently include laboratory and field evaluations of *Trichoderma asperellum* against black pod disease and *Beauveria bassiana* against cocoa mirids

(4) Use of pheromones to monitor and possibly control mirid populations.

(5) Technology transfer once the proof of concept has been established in pilot trials.

Cocoa trees in West Africa are often allowed to grow rather tall (>4 m) and in theory, IPM measures such as efficient spraying and sanitary harvesting, would greatly benefit from better control of tree height. We argue that, on a world-wide scale, better management of tree architecture remains one of the most important and tangible precursors to successful pest management. There is also perhaps less of a division between research and implementation/extension than in OECD countries, with scientists regularly being invited to carry out trials on smallholder farmers' cocoa. This requires an especially rigorous approach to safety and sustainability of pest management techniques - which may be very different from the methods originally used to establish fungicide and insecticide application to the crop.

Challenge of improving cotton competitiveness in a distorted market: analysing the role of crop protection in Francophone Africa

M Fok, M Vaissayre
CIRAD, Av. Agropolis TA B10-02, 34398 Montpellier Cedex 5, France
Email: michel.fok@cirad.fr

A Renou
CIRAD, Niaréla, BP 1813, Bamako, Mali

From the perspective of the Least Developed Countries (LDCs), the WTO Ministerial Meeting in Cancùn in September 2003 was dramatic in the sense that a few of these countries spoke for the first time in the arena of international negotiations of trade. Four Francophone African cotton producing countries (FACCs) - Benin, Burkina Faso, Chad and Mali - protested against the subsidies in a few countries or regions that had in effect pushed the world cotton price down. This approach of international protest captured the attention and energies in and out of the related countries, but no complementary actions were taken to gain competitiveness and enable them to be less dependent on the good will of the super powers. The exclusive focus on international protest is furthermore debatable as there has been no progress on the Doha negotiations since July 2006. Many actions could be contemplated to improve field productivity and product competitiveness, in various areas, e.g. soil fertility and fertilizing, tolerance to unfavourable climatic trend, cultivation practices in better controlling plant growth. In this paper, we focus on the possible contribution of crop protection.

Although the improvement of field productivity calls upon, *in fine*, new or adjusted techniques, the conditions of its implementation depend on the prospects of world market price and the evolution of the cotton trade at international level. However, in contrast to the implicit assumption of the FACCs in their protest before WTO, the abolition of cotton subsidies will not increase the world price substantially, and will not increase it for long. There is no reason to think that the imbalance between offer and demand would not remain erratic. So globally, low and volatile prices will remain however effective the correction of the current cotton subsidies will be. Consequently, for resource-poor and risk-adverse smallholding growers, productivity gain should not be contemplated at any cost or at any financial risk.

In the area of commodity trade, there is no unique price, but differentiated prices. Price differentiation does not only lie on objective and measurable criteria. On one side, owing to the general phenomenon of market concentration, one can fear that price differentiations would become less objective, less transparent and less favourable to selling countries. On the other side, the increasing sensitiveness of consumers to the environment implies that the modalities of crop protection could impact on price differentials between cottons or producing countries. Market premium offered to organic cotton or fair-trade cotton is quite illustrative of this phenomenon. Thus improvement of crop protection would not only impact on cost reduction, but also on the value of the cotton product, provided that publicity is made to show how and why techniques are implemented, and whether there is an improvement on environmental impact.

The progress of cotton production in the FACCs is commonly regarded as a rare 'success story' in Africa, these countries combined have attained over the last fifteen years third place rank in exporting cotton to the world market. Many factors have contributed to this achievement, in particular a commendable attention to crop protection by all cotton growers. The rather limited extent of cropping intensification implies a competitive production cost at the field level, but the gap between the production cost and at the point of export is far larger than in competing countries because of the well-known lack of infrastructures in LDCs. Hence, progress in productivity at the field level, for instance from improved crop protection, will correspond to smaller gains in competitiveness at the export position. Besides, in the FACCs, the cost to control cotton pest represents only one third of the total cash expenses of cotton growers, this means that the reduction of this cost would have a diluted effect on the total production cost.

Progress on crop protection must really be substantial to impact on productivity and competitiveness in the FACCs and there are reasonable prospects for substantial progress. Because current crop protection in LDCs is far from being optimal to reduce yield losses improvement in crop protection will lead to cost reduction and yield improvement, through a kind of "lever effect" of crop protection which is seldom emphasized. Improvement of cotton crop protection could result from several complementary methods. First, reform of the cotton sectors in several countries has led to less efficient implementation of crop protection (issues of insecticide supply, of technical assistance) requiring new rules and responsibility sharing to recover the former efficiency. Secondly, the implementation of chemical controls based on scouting or threshold basis is showing great potential to achieve higher efficiency in adjusting the chemical use to various cotton cropping practices.

Horticulture production development in many countries uses insecticides similar to those on cotton, leading to continuous cropping and pest pressure which threatens the onset insecticide resistance. Adaptation of pest control on cotton is needed and could be a source of better effectiveness. The advocators of organic production have merit by warning against the exclusive and blind reliance on chemical control. From economic perspectives, one can hardly recommend the total shift of the FACCs cotton to organic production; some ideas and tools of organic production could nevertheless be worth consideration in formulating a more effective and sustainable protection program. This approach of integration will be challenging to cotton researchers.

The interest of GM cotton to improve crop protection and profitability remains a matter of controversy. When considering as many of the results currently available as possible, it appears that cost reduction in controlling pests is not systematic, it depends on the initial number of sprays prior to GM introduction and the increase of the seed cost. The advantages and shortfalls of GM cotton use are not the same in DCs and LDCs. In LDCs, yield gains recorded were the highest, hence demonstrating the above mentioned "lever effect", but the use of GM seeds implied a great increase in cash expenses early in the cropping season. The potential benefit of using GM cotton to control pests, hence, depends on the economic conditions of using GM seeds. These conditions are far more diversified than those criticized by the opponents to GMO; there is a challenge for the FACCs to bargain the most adapted and reasonable conditions. The use of GM cotton cannot be profitable for every grower or every plot because there is and there always will be part of the cotton plots which are not in optimal conditions for satisfactory yield. Partial use of GM cotton should make sense, but it implies serious challenges in adjusting seed distribution and variety co-existence.

The full potential of IPM and biological controls – training

L Labuschagne
The Real IPM Company (Kenya) Ltd, PO Box 4001 Madaraka, Thika 01001, Kenya
Email: labuschagne@realipm.com

Increasing pressure from customers, particularly UK supermarkets, is forcing growers to consider biological options and Integrated Pest Management (IPM) techniques to avoid the commercial embarassments of illegal residues of chemicals on produce sold in the EU. Some supermarkets are considering making additional demands of growers by asking them if they can supply 'residue free' produce (i.e. not even leaving the legally permitted pesticide residues on the produce). This requires the grower to take up the use of biological controls (predators, parasites and biopesticides) actively as well as to improve effective use of Good Agricultural Practice (GAP).

IPM and GAP are the most important elements of sustainable production. However, training and capacity building are often needed to ensure that growers do not jeopardise their incomes by simply reducing chemical inputs without effective replacements for them. There are few sources of experienced consultants and trainers able to guide growers through the mine-field of 'residue-free' crop production.

Road map to 'residue free'

Most crops could be grown without having to leave a residue of chemicals on the produce when harvested. If it is possible why do more growers not choose to grow 'residue free' produce? The surprising fact is that the majority of growers are remarkabley ill informed about the life cycles of the pests and diseases which cause them substantial financial losses and are such a health and safety nightmare to manage. Few growers are aware of the identification or relevance of biological controls and most growers are likely to consider it '*only relevant to protected crops*' or '*too expensive*' or '*not effective*'.

Much of this negative press about biological control stems from the poor results which growers may have had with a commercial biological control agent. The supplier of the biological control may not have provided sufficient technical support for the product for various commercial or technical reasons.

Most novice IPM growers do not have enough field experience to make technical descisions on the numbers of beneficial insects to apply and how to integrate them within a compatible pesticide programme. Technical support is essential to a successful IPM programme, until growers have developed their capacity to manage the programmes independently. Most bio-control companies focus their sales team on protected crops, as IPM programmes are considered more easy to manage in controlled environments and these growers are more experinced IPM practitioners.

IPM apprenticeships

The Real IPM Company, based in Kenya, has a team of seven IPM consultants who work in a wide range of crops in many countries. The team has recently worked on IPM programmes in Ethiopia, Tanzania, Uganda, Ghana, Zambia, Zimbabwe, South Africa, Ecuador, Brazil, United Kingdom and Lebanon, as well as at home in Kenya. As a result of their work with leading growers, the use of biological controls on outdoor crops has proved to be not only effective, but also cost effective. Agri Famosa, an international leader in melon production from Brazil, was recently awarded the Tesco Environmental Award for its joint work with Real IPM on leafminer control on a 90-hectare per week planting programme (outdoors!).

Kenyans and Brazilians worked together to transfer protocols developed in Kenya – on the recycling of leafminer parasites from old parasitised crop debris – after the crop had been harvested. Often all that is needed is for the grower to adopt a compatible spray programme for all other pests and diseases, which will allow the leafminer parasite to survive.

Similar ground breaking work has been done with Kenyan rose growers who are sometimes lambasted by the press for over use of chemicals and pollution of World Heritage sites such as Lake Naivasha. However, leading world flower growers such as Oserian, on the shores of Lake Naivasha have embarked on an ambitious programme of biological control in a high value crop where previously the excuse for not implementing IPM was that cosmetic damage was not acceptable. Oserian has proved it is very acceptable – cheaper and better than chemicals at controlling spider mite! Residue-free, even chemical free, is now not as impossible as it was even five years ago.

Reaching the poor? About mindsets, partnerships and methodological pluralism

P Van Mele
Africa Rice Center (WARDA), 01 BP 2031 Cotonou, Benin
Email: p.vanmele@cgiar.org

More than a lack of resources, poverty is a lack of opportunities. To manage pests, poor farmers mainly rely on local solutions, often turning towards the use of botanicals and manipulation of easily-observable ecological processes. In general, they have little scope to learn from outsiders. Also, they cannot access services and information because they either lack time or money to seek them or because the information providers are not perceived as socially approachable. The lucky few that have access may find that the content of the information is contextually irrelevant. Apart from bottlenecks in knowledge assimilation, poor farmers' access to agrochemicals is limited for various well-known reasons. Where the pest management solution is bred into the seed, spontaneous diffusion between community members may take place through informal seed exchange, but adoption will be determined by the range of other traits of that particular new variety, as well as by the characteristics of their own seed stock and farming system. Evidence abounds that the poor often miss out on shaping, testing and accessing technological innovations.

To ensure social inclusion will require:

(i) research and development (R&D) agents to change their monolithic mindset;
(ii) policymakers and donors to create a conducive environment for pro-poor partnerships;
(iii) all actors to value methodological pluralism.

Changing mindsets

A first prerequisite for pro-poor development is that R&D agents have to discard their attitude of superiority and start valuing farmers' own creative powers. Although West African rice farmers have consistently listed bird and rodent damage among their top five problems, until recently R&D actors dismissed these as being simply out of their control. But slow change is taking place. Although not yet incorporated into its breeding program, the Africa Rice Center (WARDA) has initiated various steps to tackle these global pest problems. Under an IFAD-funded project, national research, extension and NGO staff were trained to identify, document and validate local rice innovations in West Africa. Out of the 38 stories collected in 2006, 29 (76.3%) dealt with pest management. An extension manual from a USAID-funded project in Uganda reports on farmers using snake skin or rotten cow lungs to repel birds during the rice reproductive phase. A key asset of local innovations is that they are scale-neutral and that farmers can apply their underlying principles in diverse contexts, opening up the scope for South-South learning platforms. Research on local innovations helps to change mindsets.

Biological control researchers in developing countries have mainly focused on the identification, rearing and application of exotic parasitoids. Their scientific hegemony, despite the rhetoric of farmer participation, leaves little space for acknowledging farmers' knowledge and the role of indigenous natural enemies. For instance, for years scientists (with few exceptions) have failed to explore the potential of endemic generalist predators, such as the weaver ant *Oecophylla* for controlling tropical tree pests on the simple assumption that they bite. Although Asian farmers have used the weaver ant for centuries, committed and convinced individuals were needed to get *Oecophylla* more widely recognised as an effective biological control agent. Irrespective of farmers' social status, endemic natural enemies are freely available in farmers' fields. Soft chemicals such as petroleum spray oils or botanicals such as neem may enhance the management of the entire pest complex further. New types of partnerships are helping poor farmers to optimize environmentally-sound pest management options and capture niche markets.

Create a conducive environment for pro-poor partnerships

With an increased understanding that pest management recommendations do not work in highly diverse agro-biological and socio-institutional landscapes, actors need to revisit and renegotiate their role in the system. A transformation from information provision to facilitating learning becomes crucial (Röling & Wagemakers, 1998). Creativity and professionalism is needed in developing farmer-education methods, but equally in engaging multiple service providers in pro-poor development.

Donors and policymakers have a responsibility in shaping and sustaining such a conducive pro-poor development environment. One such example is the PETRRA project, (Poverty Elimination through Rice Research Assistance), a five year (1999 to 2004) project funded by DFID and managed by the International Rice Research Institute (IRRI). During its life, it approved, managed and supported 45 research projects – on pro-poor policy, technologies and uptake and extension. Although its value-based, competitive tender approach proved highly successful in Bangladesh, the donor decided to discontinue its support and try out something completely different. Nevertheless, PETRRA showed that grassroots organizations play an important mediating role between the public sector, private sector and farmers, but often require specific technical, organizational and methodological support. Partner organizations either focused on social issues while lacking agricultural expertise, or they focused on agricultural development while lacking social inclusion mechanisms. Thematic experience-sharing and capacity-building workshops were intertwined with tailor-made institutional learning exercises to build shared values, while equal emphasis was paid to building strategic partnerships.

Methodological pluralism

Methodological diversity in the system allows R&D actors to tap into their own organizational strengths and explore what works best for them under which conditions. Diversity also enables them to play the card of complementarity. Although performative participation such as farmer field schools (FFS) and participatory plant breeding reduce the influence of local elites, complementary methodologies may be needed to 'democratize' knowledge generation within and between rural communities further. Video for farmer-to-farmer extension, picture songs, 'going public' in the sense of seizing the opportunities of public places like markets are but few of the examples applicable in pest management programs targeting the poor (Van Mele *et al.*, 2005).

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Pesticides and poverty – analysing pesticide use context (PUC) to unleash the benefits without the backlash

H M Dobson
Natural Resources Institute, Chatham Maritime, Kent, ME44TB, UK
Email: hans@dobsons.demon.co.uk

K A Jones
CropLife International, 143 Avenue Louise, B – 1050, Brussels, Belgium

Introduction

Most poverty is in the developing world – particularly in sub-Saharan Africa. Pesticide use in Africa as a whole has increased by approximately 30% since 2002. Some view this as increasing dependency, others as uptake of a successful technology, but it seems clear that pesticides are helping to increase production to feed and sustain the expanding developing world populations. The systems and circumstances in which pesticides are used – here referred to as the pesticide use context (PUC) – strongly influence the balance between benefits and risks. It is necessary to examine, and where necessary, strengthen the capacity of all aspects of the PUC to ensure a favourable balance on the benefits side.

Beneficial effects of pesticides on poverty

Pesticides have great potential to alleviate poverty, reduce drudgery, suffering and environmental degradation (Cooper & Dobson, 2007). For example, fungicides allow tomato and potato production to continue into the rainy season when farmers benefit from a ten-fold increase in prices. Herbicides liberate labour for other activities, reduce the drudgery of hand-weeding, reduce the fuel required for mechanical cultivation, and allow communities hit hard by HIV/AIDS to keep weeds under control over a larger area than would be possible by hand weeding.

Resource-poor communities are ravaged by a wide range of fatal and debilitating vector-borne diseases, including malaria, onchocerciasis, filariasis, Dengue fever, Yellow fever, diarrhoeal diseases, trachoma, leishmaniasis and sleeping sickness. These act as brakes on economic and social development since people suffering from them cannot farm properly, and those that die leave families less able to cope. This results in reduced agricultural yields, lower incomes, poorer nutrition and, in turn, increased susceptibility to other diseases. Pesticides used to control the arthropod vectors of such diseases can help to break this vicious circle.

Preventing the backlash

Just as with other powerful technologies such as motor vehicles and domestic electricity supplies, the use of pesticides carries associated risks. If not used properly, pesticides may not work effectively, they may induce resistance, or they may pose a risk to users, communities, consumers or the environment.

Given that literature on pesticides in the public domain is almost exclusively negative, there is a danger of a public perception that the risks outweigh the benefits. What is required is more information on benefits and risks to produce a better-informed debate, as well as a systematic approach to the capacity strengthening interventions required in each PUC, in order to ensure that the benefits are maximised and the risks are minimised. Strengthening the capacity of the PUC is more than just training operators. There are several key areas that must be harnessed to influence the risk/benefit balance.

The policy/regulatory framework: a registration system is required that makes safe and effective pesticides available and prevents access to inappropriate, illegal or counterfeit products, Also required are policies that support IPM and ICM, provide information, encourage trade and improve access to markets (roads, fuel taxation, security etc) so that the benefits of sustainably increased yields are realized.

Equipment design and access is crucial too: sprayers must be safe and durable to protect operators, and there must be a supply of spare parts and alternative nozzles so that they can be kept operational and adjusted for different targets. Personal protective equipment that is appropriate to the climate, culture, product and application system must also be available. In Cameroon, the law now prohibits importation of any sprayer that does not meet the FAO Minimum Requirements – a move that, at a stroke, protects operators from the most hazardous and inefficient application equipment.

The third factor is user practise. The ability and willingness to choose and use pesticides safely and effectively can determine efficacy, resistance levels, operator safety, environmental impact, market access and consumer safety. There are three main requirements: knowledge, skills and positive attitudes, and the specifics must be identified by a detailed needs-assessment, built on an analysis of the pesticide-related tasks involved.

1. Knowledge - this may be incorrect or incomplete. For farmers to use pesticides in an IPM system there is a requirement for a basic minimum knowledge on a range of key technical areas. Provided there exists a motivation to acquire this knowledge, it can be acquired through various passive means such as newspapers, books, posters, leaflets, radio, television, as well as by formal teaching.

2. Skills - the ability to do things – may also be incorrect or incomplete. Skills are best acquired through active means such as farmer days, participatory training courses, mentoring and supervised practice.

3. Positive attitudes – without these, the other two above are redundant. The building of positive attitudes is best tackled by longer term information and communication campaigns via multiple media and, as a result, is often omitted.

Strengthening the capacity of existing and potential PUCs associated with poverty alleviation is in the interest of all stakeholders – national governments, regulatory authorities, donors, sprayer/pesticide industry, NGOs and the beneficiary communities – and can probably only be achieved by a collaboration between all of them. There are already many examples of these partnerships across the world, but more are needed.

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Optimizing locust monitoring in Central Asia using remote sensing tools

A V Latchininsky
University of Wyoming, Department 3354 - Renewable Resources, 1000 E. University Avenue, Laramie, WY 82071-3354, USA
Email: latchini@uwyo.edu

R Sivanpillai
University of Wyoming, Wyoming GIS Center, 1000 E. University Avenue, Laramie, WY 82071, USA

H Wilps
Project 'Sustainable Control of Pest Locusts in Central Asia,' c/o GTZ Office, Abdullaev Str. 2A, 100100,Tashkent, Uzbekistan

Protecting crops from a locust plague continues to be a challenging, expensive, and environmentally hazardous venture which often requires coordination among affected countries and donors. For instance, the cost of containing the Desert locust upsurge in West Africa in 2003-2005 exceeded US $400 million, with 13 million ha treated with broad-spectrum insecticides in 26 countries. Though containment amidst an ongoing outbreak is essential, national and international agencies are also focusing on monitoring locust habitats and early warning systems. One of the advantages of early monitoring programs is the ability to focus on the vegetation characteristics and other land cover features which make the habitats prone to locust infestations.

Ground-based monitoring and surveys for locust egg-pods or nymphs can be an arduous task because the habitats of most locust species occur in vast, rugged or inaccessible terrain. This is particularly true for Central Asia where locusts thrive on vast and sparsely populated areas. One of the most notorious pests is the Migratory locust *Locusta migratoria*, which inhabits stands of common reed *Phragmites australis* along rivers and lakes but it can travel long distances until it finds crop fields to devour. Its biggest breeding area is situated in the River Amudarya delta near the Aral Sea in SW Uzbekistan. This delta provides favorable wetland conditions for locust survival and reproduction. The sandy river banks serve as egg-laying sites, while the reed stands furnish food and shelter for hoppers and adults. The outbreaks occur at irregular intervals, last for several years, and devastate the irrigated crops nearby. Locust swarms can disperse in different directions covering distances of over 1,000 km. Locust infested areas average 300,000 ha per year, and, during outbreaks, the areas of reeds treated with insecticides exceed 500,000 ha annually. The principal goal of locust control is to prevent the development of the dense swarms capable of emigration flights out of the reeds into crop areas. Traditional, ground surveys are cumbersome, costly and inefficient. According to the guidelines for the ground locust survey, the average daily area inspected by a professional scout is comprised of between 100 and 150 ha. Hence, a team of 20 scouts (the number of locust personnel working in the Amudarya delta) will take between 11 and 16 months to survey the entire 1 million ha delta. In the real world, the nymphal survey period is limited to three to four weeks. Identification of reed areas as potential Migratory locust habitats is the key to successful management of this pest. Remotely sensed data could be a viable source to provide the information on reed distribution on a periodic basis. Certain satellites like NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) collect information on a daily basis, and the data are free of charge. Multi-temporal MODIS data, collected at different times of the growing season, were used to generate spectral-temporal signatures for reeds and other land cover classes. These signatures were matched with reed phenology. For this study, we developed a land cover classification scheme consisting of six classes to assign to pixels in the satellite imagery (Sivanpillai & Latchininsky, 2007). Based on the predominance of reeds in the vegetation cover, these six thematic classes have also been assigned different levels of risk as potential locust habitats (Table 1).

The overall accuracy of the classified image was 74%, and most of the classification error could be attributed to the overlap between reeds and shrubs, and shrub classes. Producer accuracy values for the rest of the classes ranged between 77% (sandy soil) and 87% (reeds). The producer accuracy value for reeds indicates that the classification method used in this study was able to identify 87% of the ground reference points correctly. Multi-temporal MODIS data were successful in identifying sparse vegetation (84%), sandy soil (77%) and water (80%) in the study area. The producer accuracies for shrubs, reed, and shrub mix were 51% and 58%, respectively, indicating lower accuracy because of the overlap between these classes which represent low to moderate risk of locust infestation.

Table 1. Classification scheme used in the land cover mapping based on the potential risk as a locust habitat.

Class name and description	Risk as locust habitat	Area, ha (% of study area)
Reeds (sites with reed monoculture)	High	399,262 (18%)
Reed and shrub mix (sites with reeds and other, mostly shrub, vegetation)	Medium	137,700 (6%)
Shrubs (sites with mostly shrubs and very few reeds)	Medium/Low	204,612 (9%)
Sparse vegetation (sites with meager vegetation cover of shrubs and grasses)	Low	490,681 (22%)
Sandy soil (sandy soil sites with virtually no vegetation cover)	Low	897,131 (39%)
Water (includes water in shallow lakes, rivers, and the Aral Sea)	Low	130,631 (6%)

Despite its relatively low spatial resolution (250 m), multi-temporal MODIS data were able to capture the distribution of reeds adequately. Estimates derived from MODIS data indicate that 18% of the study area was covered by reeds which represent the highest risk of locust infestation (Table 1). Thus, instead of blanketing the fragile wetland ecosystem of the Amudarya delta with chemical anti-locust treatments, plant protection specialists can use this information to devise ecologically sound and better targeted pest management plans. This will reduce the adverse environmental impact in the zone of the Aral Sea ecological catastrophe. MODIS methodology to identify reed stands can be applicable to the Migratory locust habitats in other geographic areas.

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Closing the yield gap by education: plant protection by distance education

J E Foster, C I Reimers-Hild, E A Heinrichs
Department of Entomology, University of Nebraska-Lincoln, NE, USA
Email: jfoster1@unl.edu

Over the next two decades the developing world will continue to face a huge demand for quality education. Many universities are in a unique position to help address these challenges and at the same time shore up enrolments and further internationalize their own institutions. In summary, we are witnessing a convergence of interest between the global university community and the educational needs of students in developing countries. Governments, private institutions, and families in many developing countries have longstanding traditions of turning to European and US universities for training, technology transfer, and enhanced job opportunities. These individuals were expected to return, staff universities and government ministries, and thus serve as conduits of knowledge and skill from the industrialized to the developing worlds, although increasingly these students do not return to their countries of origin. In a recent report, 'Knowledge for Development', the World Bank argues compellingly that knowledge is the engine for development. The revolution in digital global telecommunications will affect many aspects of international education as we know it. New web-based delivery systems, in contrast to many of the television, satellite, and cable communications used in the past, are not restricted to national boundaries. In the 19th century the Land Grant system in the US started new universities. Now the new resource for higher education is not land, but band width. US universities will be the Web site on computer terminals. The major mechanism for international involvement by higher education institutions in US government agencies is particularly the United States Agency for International Development (USAID). The relationship between USAID and higher education institutions strengthened greatly with the enactment of legislations that created the Board for International Food and Agricultural Development (BIFAD)

Agriculture dominates the economies of most developing countries and has a critical impact on stimulating overall national economic growth, especially rural income, as well as a major influence on poverty alleviation. The USAID participant training office has decline in recent years due in part to a sharp reduction of numbers of long-term international students from approximately 9,100 a decade ago to 1,200 now, perhaps caused by such factors as a reduced number of USAID grants, the difficulty associated with obtaining visas to visit the USA and increased opportunities elsewhere. USAID has made many recommendations for strengthening the partnership between USAID and Land Grant universities. As one example, the following recommendation applies directly to distance education efforts. There should be increased use of modern communications technologies, distance learning and sandwich programs to reduce costs and make studies more relevant to national conditions and cultures. Graduate students should be encouraged to conduct project related research and write theses on subjects associate with the project activities.

The University of Nebraska-Lincoln is one of many universities that have a long and valued reputation for delivery of quality distance education. The University of Nebraska-Lincoln has had a long term involvement in international training of graduate students, education and research programs and USAID funded programs and it has been delivering successful distance education degrees in agriculture via the Master of Science in Entomology and the Master of Agriculture qualifications.

We have been involved in developing and teaching two of these courses at both the undergraduate and the graduate level. The course, 'Host Plant Resistance to Insects' has been taught in the classroom for 30 years and by distance for the past six years. Data clearly show there are no differences in learning outcomes based on delivery in classroom or by distance, when the students are given the same examination. Course learning assessments show that there no statistical difference in the grades or learning outcomes of students in the classroom and by distance delivery. A second course 'International Plant Protection' is singular in that we could not find a single course or a text with the focus on this topic. In 'International Plant Protection', we cover topics of plant protection from all aspects and all traditional disciplines. Additionally, we assign readings and have open discussions on multiple topics that influence plant protection, such as, cultural, ethnic, religious, gender, social, political, education level and economic topics that influence plant protection.

The focus of teaching International Plant Protection to a global audience is about problem solving. Students are assigned to teams with the objective of solving case studies from developing countries. For example, a problem is proposed, the students provided background information and then requested to research and consult any source for answers. Because the students are from many different countries, we structure the course for asynchronous learning, where communications do not require participants to exchange information at the same time, hence, email and chat rooms are password protected and accessed only by the team participants and instructors.

The two courses with primary objective of plant protection, 'Host Plant Resistance to Insects' and 'International Plant Protection', were developed for distance delivery. The results of teaching these courses multiple times and the use of rigorous learning assessment tools have provided convincing evidence that the students in the classroom and those taking the course by distance performed comparable. Thus, we are now prepared to offer non credit and certificate programs to address the needs in plant protection education. These courses are examples of the type of training that is being offered and we are convinced that distance delivered education of this type is an important component in helping towards closing the yield gap.

Organic soil fertility amendments as a tool in integrated pest management in vegetable production in Uganda

J Karungi, S Kyamanywa
Crop Science Department, Makerere University, PO Box 7062, Kampala, Uganda
Email: jkarungi@agric.mak.ac.ug

B Ekbom
Department of Entomology, Swedish University of Agricultural Sciences, PO Box 7044, S-750 07Uppsala, Sweden

Introduction

Three seemingly separate problems, i.e., crop wastes accumulation in urban markets, insect pests' induced yield losses and soil nutrients deficiencies needed intervention in the vegetable production systems in Uganda. Could the problems be solved together? In Uganda, where inorganic fertilizers are un-attainable for the majority of farmers, organic inputs offer a potential soil replenishment strategy, more so in peri-urban areas where huge quantities of market crop wastes (MCW) are readily available. What research is required before recommending use of these wastes as organic soil amendments in vegetable production? The following questions needed answers:

(i) can utilization of MCW have an effect on the development of insect pest populations in the crop?
(ii) can the MCW promote the abundance of beneficial insects?
(iii) can the plants derive enough nutrition from the MCW so as to produce good yields?
(iv) is use of MCW profitable for the farmer?

The goal of the research was, therefore, to understand implications of using market crop wastes as soil amendments in integrated pest and soil nutrient management in vegetables.

Methodology

The effect of the crop wastes was assessed in the field and greenhouse on two popular vegetables i.e. beans and cabbage. A randomized block design was used in all the trials (potted and field) with the following treatments:

(i) MCW compost incorporated in the soil;
(ii) un-composted MCW incorporated in the soil;
(iii) un-composted MCW applied as a surface mulch;
(iv) a conventional chemical fertilizer (NPK) incorporated in the soil;
(v) the untreated control.

The organic amendments were applied at the rate of 12t/ha whereas NPK was applied at a rate of 70 kg N/ha, 50 kg P/ha, and 50 kg K/ha. Data were collected on plant height and width, leaf area, tissue toughness and nitrogen content. Two pest guilds were assessed per crop, (i.e. suckers and chewers). *Aphis fabae* and *Maruca vitrata* were the pests studied on beans whereas for cabbage, the aphids *Brevicoryne brassicae* and *Myzus persicae* and the caterpillar *Plutella xylostella* were investigated. The occurrence of natural enemies associated with these pests was also recorded. Crop yields were assessed at harvest, and were subjected to economic analysis. Soil analyses were always done before planting and after harvests.

Results
Plant growth attributes were more enhanced in MCW plots as compared to NPK and the untreated plots. *A. fabae* on beans was significantly influenced by the treatments across the seasons, whereas *M. vitrata* was not.

Plots receiving the un-composted MCW as surface mulch always sustained the highest *A. fabae* infestations, in season three, mulched plants showed a 411% increase in *A. fabae* infestation compared to those in the untreated control.

For cabbage, the abundance of both aphid species and *P. xylostella* was significantly highest in composted MCW plots in seasons two and three, and the two pest groups were positively correlated. Plots that had the highest pest infestation also had the highest occurrence of natural enemies. Treatment effects on yield from soil amendments for the two crops was quite distinct; for cabbage a 56 - 118% increase in yield from MCW amended plots as compared to the un-amended plots, was apparent at the first harvest; whereas for beans a 20 - 35% increase in yield from the MCW plots was only realized after two seasons of amendment applications. Bean yields from MCW plots were comparable with those from NPK plots; however, higher economic returns accrued from the use of NPK. For cabbage, MCW plots surpassed NPK plots both in yield and economic returns. Use of MCW compost in cabbage production gave a net benefit of Uganda shillings 4,041,820 per hectare (~ US$ 2420/ha) over that of NPK (Table 1).
For both crops, a season of MCW soil amendment application resulted in higher pH, organic matter content, and levels of P, K, Ca, and Mg as compared to soil from NPK or untreated plots.

Table 1. Net benefits from the different soil fertility amendments: pooled for three seasons

Treatment	Beans (UGSh/ha)	Cabbage (UGSh/ha)
Composted MCW – incorporated	-791,672	6,072,834
Un-composted MCW- incorporated	41,534	6,457,200
Un-composted MCW on surface	104,757	5,197,070
NPK incorporated	193,097	2,031,014
Untreated control	359,167	1,842,667

1US$ = 1670UGSh

Conclusion
Experimental MCW soil fertility amendments increased infestation of *A. fabae* on beans, and aphids and *P. xylostella* on cabbage. On the bright side, the MCW amendments enhanced crop growth attributes, the insect pests' natural enemies, yield performance, and soil properties. In the promotion of sustainable agro-ecosystems, the goal is not to eradicate pests but to manage them so that they do not cause economic loss to the producers. This study has established the foundation for the utilization of MCW, previously handled as garbage to be disposed, as a key component in integrated management of insect pests and depleted soils in crop production in Uganda and probably beyond.

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Cereal Cyst Nematode (*Heterodera avenae*) is causing damage on wheat in Henan: the bread basket of China

L Hong-lian, Y Hongxia, W Xujin, Y Weixing
College of Plant Protection, Henan Agricultural University, Zhengzhou, Henan 450002, China
Email: honglianli@sina.com

J M Nicol
CIMMYT (International Maize and Wheat Improvement Center), ICARDA-CIMMYT Wheat Improvement Program, Turkey Office, Ankara, Turkey

Cereal cyst nematode (CCN) - a serious problem of Henan wheat production

China is the world largest wheat producer with over 120Mt of wheat with average yields around four tonnes per hectare. Cereal cyst nematode (CCN) *Heterodera avenae* is reported to be one of the most economically important and damaging nematode of wheat worldwide (Nicol *et al.*, 2003). In the Hubei province of China it was first reported in 1991 and now has been found in more than 10 provinces in China representing about 2/3^{rds} of the total wheat production area (Wang *et al.*, 1991). Henan is one of the most important wheat producing provinces with both a large area (5 million ha, 4.8t/ha), accounting for more then 26% of China's annual wheat production in 2006. In Henan province, 126 soil samples were taken in 2006 and 2007, and more than 60% of these had high populations of CCN (12~107eggs /g soil). Of the 18 districts in Henan sampled in 2007, CCN was found in 15, making the area with CCN over 1.1 million ha. Lack of effective controls has resulted in CCN damage becoming more severe in Henan in recent years (Sha *et al.*, 2002, Wang *et al.*, 2005).

Yield loss estimate of CCN in Henan

In 2005-2006, preliminary yield loss studies were conducted on two widely grown wheat cultivars with a natural CCN population in farmers' fields in Zhengzhou. The experiment consisted of three replicates with and without the application of aldicarb (as Temik15G®) at 22.5kg a.i./ha. Aldicarb effectively reduced the soil population of *H. avenae* by 52.5 % and significantly (P<0.05%) increased the yields of both Wenmai 4 and Wenmai 6 by 28.8% and 40.3% respectively (Table 1).

In the 2006-2007 season, three cultivars were used for testing the yield loss in another field using the same method, but with seven replicates. The CCN population was effectively reduced by 68% by aldicarb application. As previously, aldicarb increased yields of three wheat cultivars significantly (P<0.05%) ranging from 24.3% to 42.9% (Table 1), although the field population of *H. avenae* was lower than in 2006.

Furthermore, the number of cysts per root system was significantly correlated with yield of these cultivars. These preliminary results clearly demonstrate that this nematicide gives partial control of CCN, and this nematode is economically important on Chinese wheat cultivars.

Table 1. The effects of aldicarb on wheat yield (t/ha)

Year	Cultivar	Yield control	Yield aldicarb treated	Yield increase (as % of control)
2006	Wenmai 4	7.19	9.23	28.81
	Wenmai 6	7.40	10.39	40.34
2007	Wenmai 6	7.32	9.10	24.31
	Yumai 18	7.55	9.91	31.25
	Zhengmai 9023	6.15	8.79	42.89

Preliminary research results on pathotype and resistance reaction of CCN in Henan
In order to control CCN effectively with genetic resistance, it is essential to understand the pathotype of *Heterodera avenae*. The Zhengzhou pathotype was identified using a subset of the International Host Differential Set (Group A, 11 differentials) which was developed by Andersen and Andersen in 1980. Using 6 replicates for each differential inoculated with 100 *H. avenae* juveniles at sowing and harvested after three months in controlled conditions suggested that the pathotype population is *Ha13*, which is similar to that in Australia. Further work under both controlled and field conditions is needed to validate this finding. The implications of this information are that sources of resistance identified in Australia may be effective in this region of China.

Preliminary work investigating the resistance of 32 common Chinese cultivars (lines) to the Zhengzhou CCN population was evaluated under both controlled conditions (as above) and also under natural field conditions. Preliminary results indicate that the resistance of wheat cultivars is obviously different, with most of the commonly used Chinese cultivars being highly susceptible. However, a few cultivars may offer some resistance (i.e. were less susceptible), but were not considered completely resistant.

Work has begun in Henan with CIMMYT to confirm these preliminary yield loss data, reconfirm the Zhengzhou pathotype, understand the biology, population dynamics and ecology *H. avenae* in Henan, and, most importantly, understand the reaction of Chinese and foreign cultivars to identify sources of resistance to maintain CCN populations below economic threshold densities.

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Zooming-in, zooming-out: a new approach to scale up locally appropriate innovations of regional relevance

P Van Mele
Africa Rice Center (WARDA), 01 BP 2031 Cotonou, Benin
Email: p.vanmele@cgiar.org

In Africa, for many people, rice is a new crop. Farmers and agro-processors face many challenges. Having limited chances to learn, they resort to trial and error, resulting in poor quality products. Extension systems are being decentralized with NGOs and the private sector carving out new roles. Multiple service providers develop their own extension methods and tools (Van Mele *et al.*, 2005). Participatory extension yields the best results, but initial investment costs are high. They involve interpersonal communication, negotiation, making mistakes and building trust. To strengthen innovation systems, an approach is needed that helps to merge processes and outcomes of participatory innovation development with the mass media. *Zooming-in zooming-out*, offers guiding principles.

International public goods at the CGIAR

The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is a strategic partnership of countries, international and regional organizations and private foundations supporting the work of 15 international Centers. The Africa Rice Center (WARDA) is one of the fifteen CGIAR centers. The CGIAR's mission is to achieve sustainable food security and reduce poverty in developing countries through scientific research. One of its key activities is the so-called development of international public goods, which includes products, processes and methodologies. One such approach that will contribute to a higher effectiveness and impact of research outputs is called *zooming-in, zooming-out*.

Zooming-in, zooming-out: the process

To ensure that farmer-education videos or radio programs are international public goods that do not remain on the shelf, the *zooming-in, zooming-out* approach starts with a broad stakeholder consultation to define regional learning needs. Only then are communities approached to get a better feel about their ideas, knowledge, innovations and the words they use in relation to the chosen topic (*zooming-in*). Based on the key learning needs, videos or radio programs are produced in close consultation with the end-users.

Consequently, when showing the draft programs to other villages (*zooming-out*), more novelty is identified, and further adjustments made. Partnerships are expanded while scaling up. As part of the research undertaken at the Africa Rice Center (WARDA), uptake pathways are tested for their pro-poor relevance. Two case studies from Bangladesh and Benin illustrate the role of video in scaling-up sustainable rice technologies.

Farmer-education videos

Since 2002 and through projects funded by DFID, IFAD and the Government of Japan, a range of videos were developed dealing with rice seed management, rice quality, rice agro-processing and marketing. Each followed the zooming-in zooming-out approach. The approach was documented, fine-tuned and tested.

Video, participation and impact

Evidence shows that based on a few well-selected local innovations, and merged with appropriate scientific knowledge, videos were able to explain underlying biological and physical principles. The more these principles resonated with what farmers already knew and did, the more videos became useful as a stand-alone method. Facilitation increased experimentation and adaptation of sustainable technologies, but was not always a prerequisite. The use of botanicals as insect repellants in seed storage, for instance, increased by 30% when a video was used as a stand-alone and by over 60% when video was followed by group discussion.

Both process and outcomes of participatory research increased the effectiveness of educational videos. Ideally videos should be made with graduates of farmer field schools or with farmers who embraced participatory research. The high regional relevance of the videos ensured easy uptake by multiple service providers. They were translated into more than 10 languages. Apart from strengthening public and private extension services, they influenced rural communities in Bangladesh, Nepal, India, Cambodia, Mali, Guinea, Gambia, Nigeria, Ethiopia and Uganda. By 2006, video-supported group discussions had reached about 400,000 farmers. Through the Bangladeshi national TV the videos reached over 40 million rural people. The videos were posted on *YouTube* and incorporated into the curriculum of various Western and African universities.

Rural radio

Guinean women who watched the seed health videos were interviewed later by the rural radio to share their new insights with the wider community. The resulting 25-minute program was broadcast twice a week for three months (November 2006 – January 2007). This broadcast potentially reached about 820,000 rural people in Lower Guinea. Recognizing the potential of rural radio when linked to the *zooming-in, zooming-out* approach, WARDA partners were trained to develop radio scripts. Topics described regionally relevant local innovations, including seed conservation, and bird and termite control. To enhance scaling up, scripts were hosted on the website of the Developing Country Farm Radio Network (DCFRN).

Recommendations

- Train multiple-actor media teams that are likely to sustain the collaboration
- Identify topics from participatory innovation development with regional relevance
- Produce radio or video programs with trained farmers on selected topics
- Test effectiveness of the extension materials and be flexible to adjust
- Expand partnership base while scaling up

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